Towards understanding and improving decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes

Thesis

UNIVERSITY OF SOUTHAMPTON

FACULTY OF ENGINEERING AND THE ENVIRONMENT

Towards understanding and improving decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes

by

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ABSTRACT

FACULTY OF ENGINEERING AND THE ENVIRONMENT

Environmental Sciences

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TOWARDS UNDERSTANDING AND IMPROVING DECISION-MAKING FOR THE CONSERVATION AND SUSTAINABLE USE OF INTERTIDAL MUDFLATS AND SALTMARSHES

by Natalie Michelle Foster

Evidence suggests that improvements in both knowledge and actions are required to realize the conservation and sustainable use of intertidal mudflats and saltmarshes, specifically in terms of decision-making. In the absence of known research in this field, this research aimed to understand and improve decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes, using a case study in the Solent, UK.

The study constructed a timeline of relevant events. It found that the majority of the events indirectly influenced the conservation and sustainable use of intertidal mudflats and saltmarshes, and were primarily concerned with some other purpose, such as coastal flooding and erosion risk management. Furthermore, that research, legislation and policy, and practice are interconnected in a complex web, with changes in one domain being reflected in another. Yet despite the significant investment in research and consultation processes by many people over numerous years, no clear end point appears to have been reached in terms of realizing intertidal mudflat and saltmarsh conservation and sustainable use.

Building on these findings, the study used multi-methodology systems intervention as a lens through which to view and make sense of what the existing decision-making process is, and how to intervene to change (improve) it. It found that the decision-making process fails to start out systemically, and that an emphasis on participation through consultation is perhaps not the best means of involving stakeholders. The gradual ‘closing down’ of options as a result of the above means that there is often inaction or delays in taking actions due to multiple diverse perspectives regarding what action is required, how, why and by who. An ‘improved’ decision-making process is suggested and trialled involving a social learning cycle based on systems thinking and practice, in which stakeholders engage in dialogue and work together to make decisions and take actions towards the conservation and sustainable use of intertidal mudflats and saltmarshes.

The outcomes from a pilot study workshop demonstrate that the ‘improved’ decision-making process generally proved very successful for this group of stakeholders. It engaged them in dialogue and in working together using skills and techniques in systems thinking, modelling, negotiating and evaluating, leading to new insights and shared understandings about the problem situation, and concerted actions to improve it. Notwithstanding that there are some refinements that can be made to further improve the decision-making process as a result of ‘lessons learned’ from the workshop, the participants’ feedback confirms that it was appropriate in this context, and may also be useful in other complex situations, particularly those involving multiple stakeholders from diverse backgrounds. However, it is recognized that whilst the study has made significant progress towards understanding and improving decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes, there is still further work required before the improvements can be implemented on a local, national or global scale.

Contents

List of Figures

List of Tables

Declaration of authorship

I, Natalie Michelle Foster, declare that the thesis entitled *Towards understanding and improving decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes* and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

- this work was done wholly or mainly while in candidature for a research degree at this University;
- where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
- where I have consulted the published work of others, this is always clearly attributed;
- where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
- I have acknowledged all main sources of help;
- where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
- parts of this work have been published as:

  Foster, N. M., Hudson, M. D., Bray, S. and Nicholls, R. J. 2013. Intertidal mudflat and saltmarsh conservation and sustainable use in the UK: a review, Journal of Environmental Management 126, pp. 96—104. http://dx.doi.org/10.1016/j.jenvman.2013.04.015

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Signed:

Date:

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Part I

Introduction

Chapter 1

Research overview

1.1 Introduction

People depend on the environment to meet their basic needs for food, water, air and shelter; consequently, they are in continuous interaction with it. Every person, in their multiple roles within society, is responsible to some extent for making decisions and taking actions that affect and are affected by the environment (Blackmore, 2006). For example, an individual decides what food to eat; a local authority decides whether to grant planning permission for dock development; a national government decides the strategy for addressing air pollution; world leaders decide how to deal with global challenges such as food security and climate change. Each of these decisions has an effect that reaches far beyond the individual or group making the decision (English *et al.*, 1999). Over the past 50 years, people have changed the environment more rapidly and extensively than at any other time in human history. The changes have contributed to significant gains in human well-being, but they have also resulted in substantial and continuing loss of biodiversity (Millennium Ecosystem Assessment, 2005a).

This thesis posits that if we are to continue to meet the needs of present and future generations of humans and other species, we must learn to think and act differently. Using a case study in decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes in the UK Solent region, the research presented in the thesis reveals important new insights about what *is* done and what perhaps *ought to be* done, and demonstrates how we can work together to bring about better human interventions. This chapter presents the research aim and objectives, study area and problem situation, and research design.

1.2 Aim and objectives

The aim of the research was to understand and improve decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes. The objectives were:

1. to review the conservation and sustainable use of intertidal mudflats and saltmarshes;
2. to critically appraise multi-methodology systems intervention as a lens through which to view a complex problem situation, and to make decisions and take actions to resolve it;
3. to generate an overview of events relevant to the decision-making situation;
4. to explore and analyse the decision-making process;
5. to implement changes (perceived improvements) in the decision-making process and evaluate the outcomes.

Chapters 2 to 6 of this thesis report on each of these objectives respectively, providing a summary of the work undertaken and the outcomes (see section 1.4 for further details).

1.3 Study area and problem situation

The Solent extends from Hurst Spit in Hampshire to Pagham Harbour in West Sussex and includes the north shore of the Isle of Wight (Figure 1.1). It is home to over 1.4 million people (Stillman *et al.*, 2009). There are two cities, both are major ports: Southampton for freight and cruise ships; and Portsmouth for military vessels and passenger ferries. There is also an oil refinery, an oil and gas terminal, two power stations and a waste incineration plant located within Southampton Water. The majority of this infrastructure, including the ports, is built on land reclaimed from intertidal mudflats and saltmarshes. The Solent is also extensively used by the local population and visitors for recreational pursuits, particularly sailing (Drummond and McInnes, 2001). As noted by Solent Forum (2011), in the estuaries and harbours of the Solent, there are more than 20,000 moorings for recreational boats.

Despite the Solent's heavy industrial and recreational use, the natural environment retains its importance in a local, national and international context. Over 80% of the Solent's coastline is designated for its nature conservation interest, including the intertidal mudflats and saltmarshes, as well as the species that they support, particularly overwintering and migratory wading birds and wildfowl (Drummond and McInnes, 2001; New Forest District Council, 2010). The UK Conservation of Habitats and Species Regulations 2010 dictate that there must be 'no adverse effect' to the integrity of designated areas from human developments. Where this cannot be ascertained, measures must be incorporated into a plan or project to mitigate for the risk of the perceived adverse impact. The UK

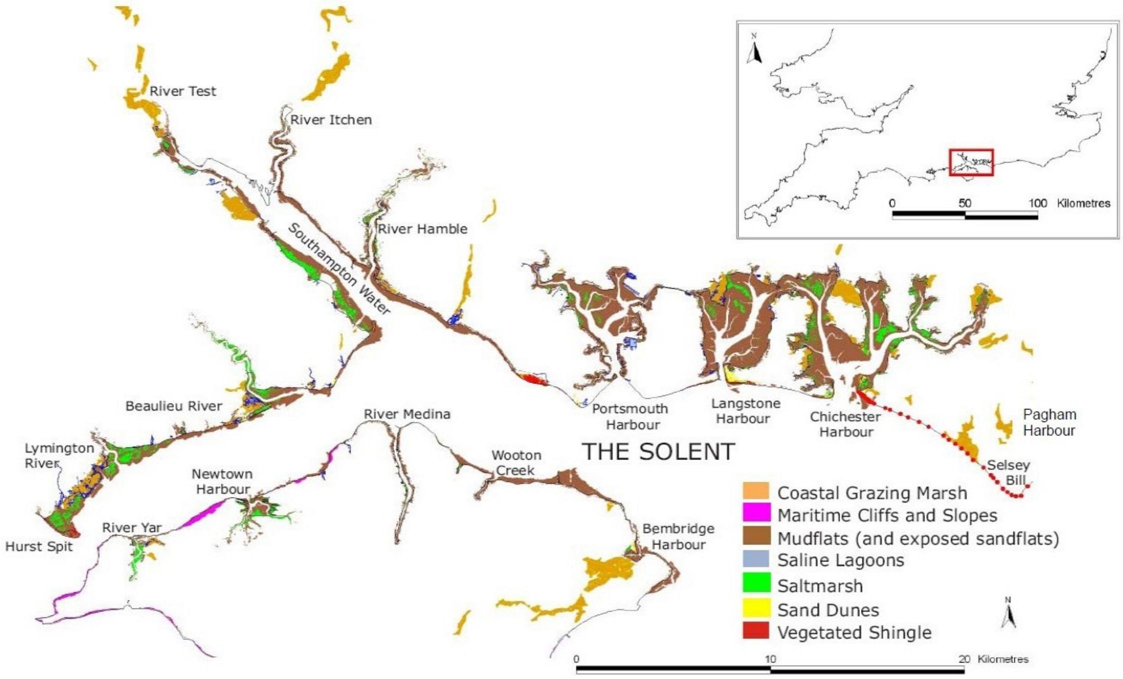

Figure 1.1 The Solent estuarine system (Cope *et al.*, 2008)

Biodiversity Action Plan specifies targets to maintain the present extent of all intertidal mudflats and saltmarshes regardless of their designation status. Furthermore, it states that provision should be made to restore the saltmarsh extent to a 1992 baseline (the year of adoption of the Habitats Directive) (UK Biodiversity Group, 1999). Across the Solent, saltmarsh loss due to erosion was c. 670 ha between 1971 and 2001; about 40% of the total area present in 1971 (derived from Cope *et al.* 2008). Predicted changes to existing intertidal habitats over the next century (based on the extrapolation of past changes) are estimated to be +60 ha for intertidal mudflats and -812 ha for saltmarshes; about a 1% gain and a 78% loss respectively (Cope *et al.*, 2008). This has significant implications for compliance with environmental policies, particularly for coastal defence.

Approximately 76% of the Solent's coastline is protected from flooding by coastal defences. The majority of these coastal defences have designated sites to landward and seaward. About 75% of existing defences will reach the end of their residual or engineering design life within 20 years; works are therefore required to manage the coastal flood risk. At least 60% of the coastline is privately owned and/or the coastal defences are maintained by third parties. Private landowners have certain permissive development rights to protect their property and to continue to maintain existing defences without the need for planning permission provided it does not constitute 'development' of any kind. These rights apply and remain regardless of shoreline and biodiversity management policies. However, there is a level of uncertainty regarding the availability and likelihood of securing public funding for defences maintained by local authorities and the continued maintenance of coastal defences by private owners. Failure or non-maintenance of coastal defences would result in a significant risk of increased flooding and adverse impacts to infrastructure, property and designated sites such as coastal grazing marsh. Assuming that all coastal defences are maintained, it has been estimated that, of the figures stated above, 5 ha of intertidal mudflats and 495-595 ha of saltmarsh will be lost due to 'coastal squeeze', where the natural landward migration of intertidal habitats in response to sea level rise is prevented by coastal defences (Cope *et al.*, 2008).

The Solent Dynamic Coast Project identified the paucity of 'managed realignment' opportunities, in which the effects of intertidal habitat loss could be compensated by the creation of new intertidal habitats via the setting back of coastal defences (Cope *et al.*, 2008). It has been suggested locally for decades (e.g. by Ranwell 1975, 1981) that the beneficial use of dredged materials to recharge existing, impoverished mudflats and saltmarshes or to create new mudflats and saltmarshes, usually where they have previously existed or nearby, offers a possible solution to the erosion problem. But, there is no evidence that this option was considered in the Solent Dynamic Coast Project. In 2012, there were two relatively small scale 'beneficial use' trials to compensate for the adverse impacts to designated sites from vessel operations (Wightlink, 2012) and breakwater construction (The Crown Estate, 2012) at Lymington, and a large scale managed realignment project as mitigation for 'coastal squeeze' was under construction at Medmerry, near Selsey Bill (Environment Agency, 2012). But, even given these actions, losses due to erosion still significantly outweigh gains from intertidal mudflat and saltmarsh reparation (IMSR) schemes.

1.4 Research design

The research used a qualitative case study design which facilitated the exploration of the problem situation within its context (Baxter and Jack, 2008). The primary rationale for the use of a single case was that it was perceived to be representative (or typical) of other UK cases (Yin, 2009). It was also more easily accessible than other possible cases, both in terms of physical location and existing networks with key stakeholders in the case.

The study was bounded by time, place and activity. As discussed in chapter 4, the time period covered by the study was a consequence of the dates of known events rather than intentionally chosen cut-off points; and the sole criterion for the inclusion of an event was that it must be perceived to directly or indirectly influence the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent in terms of research, legislation and policy, or practice.

The study employed a variety of data sources and methods of analysis. It incorporated evidence from peer-reviewed research, conference proceedings, technical reports, historical books and other types of document, as well as from semi-structured interviews and surveys with participants; and it drew heavily on systems theories, methodologies and techniques, in particular, soft systems methodology, system dynamics and critical system heuristics. This approach enabled the situation to be viewed through different lenses, which allowed for multiple facets of the situation to be revealed and understood (Baxter and Jack, 2008), and the converging lines of evidence (data triangulation) add strength to the findings (Yin, 2009).

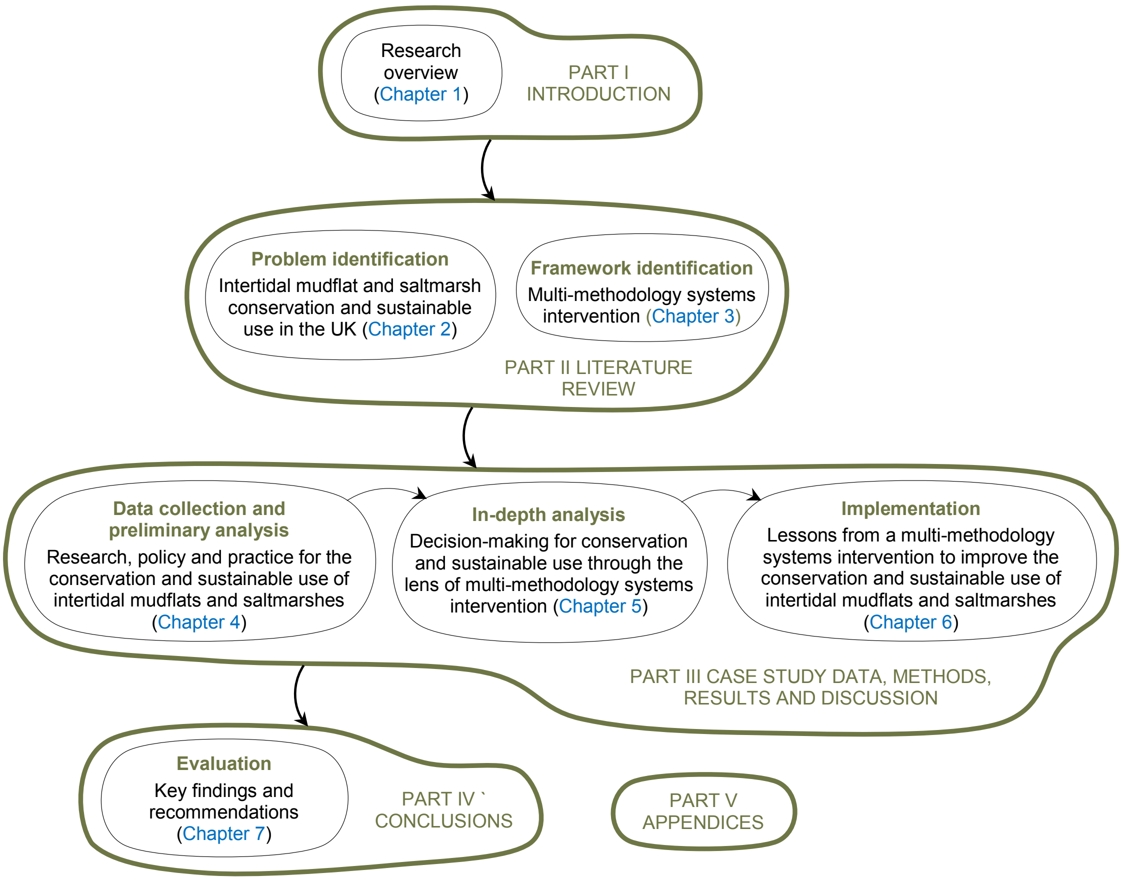

Figure 1.2 Overview of research stages

The overall research process and thesis structure is outlined in Figure 1.2. Detailed descriptions of the participants, data sources and methods used in the study are given where appropriate in chapters 4 to 6. Definitions of key concepts and terms used in this research are given in the glossary.

Part II

Literature review

Chapter 2

Intertidal mudflat and saltmarsh conservation and sustainable use in the UK[1]

2.1 Introduction

The significance of intertidal mudflats and saltmarshes to the well-being of humans and other species has been formally recognized since the adoption of the Convention on Wetlands of International Importance in Ramsar, Iran in 1971. It was reiterated in 1992 by the formation of the Convention on Biological Diversity — an intergovernmental agreement to support the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of benefits (Cardinale *et al.*, 2012). Parties committed to a more effective and coherent implementation of the three objectives of the Convention, and agreed to achieve by 2010 a significant reduction in biodiversity loss (Secretariat of the Convention on Biological Diversity, 2005). Despite these agreements, significant losses of intertidal mudflats and particularly saltmarshes have been recently reported, including in the USA (Kennish, 2001; Schwimmer, 2001; Zedler, 1996), Netherlands (Cox, 2003; Eertman *et al.*, 2002), Spain (Castillo *et al.*, 2002) and UK (Baily and Pearson, 2007; Cope *et al.*, 2008; van der Wal and Pye, 2004).

This chapter reviews the UK progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes. It presents an overview of the importance and value of intertidal mudflats and saltmarshes, their current status, the causes and consequences of their loss and the associated responses, and considers what is required to further progress towards their conservation and sustainable use.

[1]published as Foster, N. M., Hudson, M. D., Bray, S. and Nicholls, R. J. 2013. Intertidal mudflat and saltmarsh conservation and sustainable use in the UK: a review, Journal of Environmental Management 126, pp. 96—104. http://dx.doi.org/10.1016/j.jenvman.2013.04.015

2.2 Importance and value

Intertidal mudflats and saltmarshes comprise a transition zone between marine and terrestrial systems (Figure 2.1). Fine, predominantly muddy sediment accumulates to form mudflats in low energy environments such as estuaries and embayments, in the lee of barrier islands and spits, and on sheltered open coasts, where tidal current and wind-wave action are limited, and the sediment supply is sufficient to keep pace with changes in relative sea level (Allen, 2000; Allen and Pye, 1992). Halophytic vegetation develops to form saltmarsh on upper intertidal mudflats. Saltmarsh comprises a vegetated surface dissected by a network of branched, generally blind-ended creeks and salt pans (Allen, 2000).

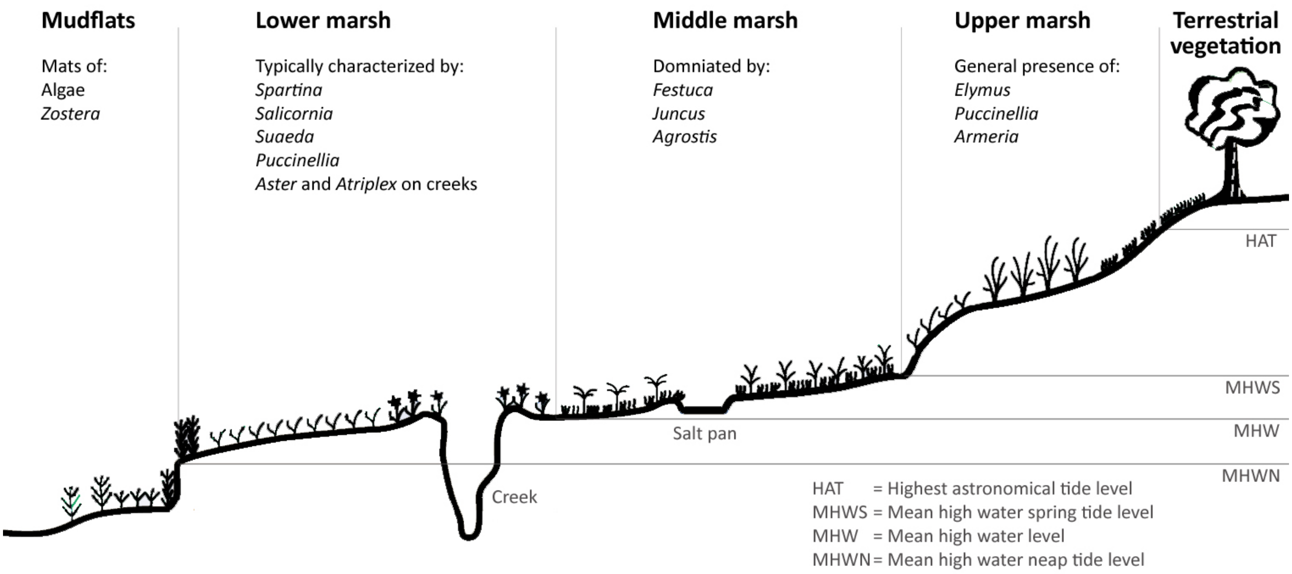

Figure 2.1 Indicative UK intertidal mudflat and saltmarsh profile (adapted from: Environment Agency 1996; Nottage and Robertson 2005; Rodwell 2000)

Intertidal mudflats and saltmarshes generate some of the highest and most valuable ecosystem services (detailed in Appendix A) upon which humans and other species depend. The primary argument for their protection and reparation is to secure and improve the continued delivery of these services (Bromberg Gedan *et al.*, 2009), particularly for nature conservation (McMullon, 2008) and coastal defence purposes (Huggett, 2008b).

Many species, including for example, the native small cordgrass (*Spartina maritima*) and the naturalized North American smooth cordgrass (*Spartina alterniflora*) are unique to saltmarshes; they can exist nowhere else (McMullon, 2008). Consequently, they are considered rare (Adam, 1993; McMullon, 2008) or vulnerable to extinction (Sharma, 2009). Intertidal mudflats and saltmarshes together are also considered particularly important for over-wintering and migratory wading birds and wildfowl, which depend on these habitats for food, nesting and roosting (McMullon, 2008). They support substantial proportions of the total world population of the barnacle goose (*Branta leucopsis*) and brent goose (*Branta bernicla*), and internationally important numbers of turnstone (*Arenaria interpres*), knot (*Calidris canutus*) and redshank (*Tringa totanus*) (Holt *et al.*, 2011). Similarly, they provide an essential nursery ground for commercially important fish stocks, such as herring (*Clupea harengus*) and sea bass (*Dicentrarchus labrax*). In 2010, capture fisheries, which are supported by these nursery grounds, accounted for £719 million in yields in the UK (Almond and Thomas, 2011; Green *et al.*, 2009). The importance of intertidal mudflats and saltmarshes in this context is reflected in national and international conservation policies and the associated designations; more than 80% of saltmarshes in Great Britain are protected by designations for their nature conservation interest (Burd, 1989).

In appropriate quantity and form, the capacity for saltmarsh vegetation to attenuate wave height and wave energy is significant (Cooper, 2005; Moller, 2006; Moller and Spencer, 2002; Moller *et al.*, 1999). This natural buffering function provides a first line of defence against coastal flooding, which considerably reduces the construction specifications of sea walls required to protect the hinterland. Physical scale models in the 1980s predicted approximately 40% wave height attenuation over an 80 m wide saltmarsh (Brampton, 1992). Based on these results, it has been suggested that capital cost savings per metre of new sea wall range from £1500–£3500 for a 6 m high sea wall fronted by 6 m of saltmarsh to £2600– £4600 for a 3 m high sea wall fronted by 80 m of saltmarsh when compared to the cost of building a 12 m high sea wall in the absence of saltmarsh in 1990s prices (Dixon *et al.*, 1998; King and Lester, 1995). However, empirical evidence from recent field studies suggest that saltmarsh can attenuate waves to a higher degree than predicted by the models. For example, over a 10 m width of saltmarsh at Bridgewick on the Dengie Peninsula in Essex, wave height and wave energy decreased by an average of 44% and 79% respectively (Moller and Spencer, 2002); over a 300 m width of saltmarsh at Wrangle Flats in the Wash, wave height decreased by an average of 91% and wave energy by an average of 97% (Cooper, 2005). Thus, as noted by Moller (2003), the 1990s 'best guess' estimates of the coastal defence value of saltmarshes need revising in the light of the new evidence. Even so, given that an estimated 2000 km of UK coastline is protected by saltmarsh (Doody, 1992), its coastal defence value is in any case substantial.

Aside from the above, intertidal mudflats and saltmarshes play a vital role in the processing of nutrients, water and soil, provide human food, fibre, fuel and biochemical resources, regulate climate, disease, coastal erosion and pollution, and provide a backdrop and inspiration for recreational activities such as painting, walking and birdwatching (see

Appendix A).

According to a working report for the UK National Ecosystem Assessment (2011a), estimates for the total economic importance of coastal wetlands are highly variable, with an upper value of £786 million per year, although Pascual *et al.* (2010) point to limitations in the methods and urge careful consideration of the assumptions made (Morris and Camino, 2011). Nonetheless, the Millennium Ecosystem Assessment (2005b, p. 34–35) concludes that 'regardless of the ongoing debate about the means of calculating the economic value of wetlands, it is now well-established that they are valuable and deliver many services for people'.

2.3 Current status

International conservation initiatives such as the Bonn[2] and Biodiversity[3] Conventions, implemented in the UK by the Habitats and Species Regulations 2010[4] and Biodiversity Action Plans respectively, as well as flood and coastal erosion risk management, require accurate knowledge of the current status and trends of intertidal mudflats and saltmarshes (Environment Agency, 2011). However, the mapping of the geographical distribution and extent of intertidal mudflats and saltmarshes is variable; as illustrated by the evidence presented here, the former are poorly catalogued compared to the latter, but in both cases, there is considerable uncertainty in the current UK status as a result of old, poor quality or incomparable data from a number of different sources.

Intertidal mudflats and saltmarshes are widely distributed around the UK coastline. The largest expanses are in the major estuaries and embayments of eastern and north-west England and in Wales, with concentrations of smaller areas in the estuaries of southern and south-eastern England, the firths of eastern and south-west Scotland, and the sea lochs of Northern Ireland. North-west Scotland is characterized by a large number of very small saltmarsh sites at the heads of sea lochs, embayments and beaches (Buck, 1993).

Except in Wales (see below), there are no known field surveys of UK intertidal mudflats. Estimates for the current extent are based on Buck (1993). In a review of estuaries initiated in 1988, Davidson *et al.* (1991) estimated a total of 265,688 ha of intertidal mudflats in Great Britain by subtracting the area of saltmarsh from the total intertidal area. The saltmarsh area was determined pro rata from Burd (1989). The total intertidal area was determined from extreme high water spring tide level (interpreted as the

[2]Convention on the Conservation of Migratory Species of Wild Animals, ratified in 1985
[3]Convention on Biological Diversity, ratified in 1994
[4]Conservation of Habitats and Species Regulations 2010 (SI 2010/490) as amended

upper boundary of mapped saltmarsh, sand, mud, rock or shingle symbol or shading on 1:25,000 OS maps and then marked on 1:50,000 OS maps) to low water mark as shown on 1:50,000 OS maps (mean low water in England and Wales, and low water spring tide level in Scotland). Using the same approach, Buck (1993) revised and updated the total intertidal area and saltmarsh figures from Davidson *et al.* (1991). Based on the updated figures, the intertidal mudflat extent can be calculated to be 278,816 ha in the United Kingdom, comprising 267,831 ha in Great Britain and 10,985 ha in Northern Ireland. Estuaries are treated as whole units which take no account of national boundaries within Great Britain. Thus, attempts to determine the extent in England, Scotland and Wales (e.g. by the Biodiversity Action Reporting System) based on Buck (1993) are best guess estimates only. In Wales, an innovative survey mapped the entire intertidal zone (excluding saltmarsh). Fieldwork was undertaken by an in-house team of surveyors from the Countryside Council for Wales from 1996 to 2004. The survey method was based on the use of aerial photographs of less than 5 years old and taken not more than two hours either side of low water springs, the latter to be consistent with the survey duration. These were used as templates to produce 'wireframe' maps on to which biotopes were drawn in the field and subsequently digitally mapped. It established the extent of intertidal mudflats in Wales to be 14,303 ha (Brazier *et al.*, 2007).

Burd (1989) surveyed the saltmarshes of Great Britain between 1981 and 1989 using field sketches to estimate the composition of the main vegetation types and the saltmarsh extent. In some areas, the survey drew on existing surveys dating back to the early 1970s. Since then, surveys have been *ad hoc* and fragmented. The Environment Agency (2011) coordinated a survey of England and Wales, which mapped the saltmarsh extent from high resolution digital aerial photographs taken between 2006 and 2009. It determined the extent to be 33,572 ha in England and 6,950 ha in Wales. Estimates for the current saltmarsh extent in Scotland are still generally based on Burd (1989), which stated the amount to be 6089 ha. An unpublished report by Posford Duvivier Environment (1998) calculated an area of 6567 ha based on aerial photographs from the Land Cover of Scotland 1988 data set. More recently, Scottish Natural Heritage estimated 7766 ha by amending the results of Burd (1989) based on local knowledge (Ellis and Munro, 2004). A major survey of the entire Scottish saltmarsh resource, jointly commissioned by Scottish Natural Heritage and Scottish Environmental Protection Agency, commenced in summer 2010 and is expected to report on vegetation composition and extent in 2014 (Angus *et al.*, 2011, T. Haynes, *pers. comm.*). In Northern Ireland, the best estimate of the current extent by the Department of the Environment (DOE) is 239 ha (Boorman, 2003), based on a combina-

Table 2.1 Best guess estimate of the 2012 UK intertidal mudflat and saltmarsh extent

Habitat	Location	Extent (ha)	Source
Intertidal mudflats	England Wales Scotland	14,303	Brazier *et al.* (2007)
	Great Britain (GB)[a]	267,831	derived from Buck (1993)
	Northern Ireland (NI)	10,985	Buck (1993)
	UK[b]	278,816	derived from the extents stated for GB and NI
Saltmarsh	England	33,572	Environment Agency (2011)
	Wales	6,950	Environment Agency (2011)
	Scotland	6089–7766	Burd (1989); Ellis and Munro (2004)
	Great Britain	46,611–48,288	derived from the extents stated for England, Wales and Scotland
	Northern Ireland	239–905	Boorman (2003); Cooper *et al.* (2009)
	UK	46,850–49,193	derived from the extents stated for GB and NI

[a] Great Britain comprises England, Scotland and Wales
[b] United Kingdom comprises Great Britain and Northern Ireland

tion of unpublished data from a survey of selected locations by Cooper *et al.* (1992) and individual site reports by DOE staff (P. Corbett, *pers. comm.*). However, this figure is inconsistent with the findings from the most recent Northern Ireland Countryside Survey in 2007, which estimates a total of 905 ha, based on statistical analysis of 19 field sampling squares across all intertidal substrate types from 1 m above highest astronomical tide (to take into account transitional saltmarsh communities) to mean low water (Cooper *et al.*, 2009). By cumulative addition, the best guess estimate of the current UK saltmarsh extent based on the evidence presented here is 46,850–49,193 ha (Table 2.1).

2.4 Characteristics and rates of change

Change in extent is a reliable indicator of conservation and sustainable use (Cooper *et al.*, 2009). But, in the absence of good quality baseline survey data, assessing rates of change of intertidal mudflats and saltmarsh is problematic. Nevertheless, several studies in England and Wales (e.g. Baily and Pearson, 2007; Bray and Cottle, 2003; Cooper *et al.*, 2001; Environment Agency, 2011; Lee, 2001; Pye and French, 1993) have attempted to do so, primarily to assess habitat creation requirements and opportunities in order to meet the legislative obligations of conservation policies such as the UK Habitats and Species Regulations 2010. There was no evidence of similar studies in Scotland or Northern Ireland.

Pye and French (1993) estimated that 8,000–10,000 ha of intertidal mudflats would be lost due to erosion associated with the landward movement of the low water mark in response to sea level rise in England between 1993 and 2013 (c. 400–500 ha per year), mainly in southern and south-east regions. Lee (2001) predicted a similar trend, estimating losses of 11,459 ha intertidal mudflats due to sea level rise in England and Wales between 1998 and 2048 (c. 230 ha per year). Without hard evidence, actual changes in the UK extent are uncertain. But in any case, the situation is more ambiguous and complex than these studies suggest. For example, Bray and Cottle (2003) predict a 60 ha increase in intertidal mudflat extent in the Solent (central southern England) by 2100 (c. 1–2% of the 2001 resource) due to the conversion of saltmarsh to intertidal mudflats despite retreat of the low water mark.

The Environment Agency (2011) attempted to compare their 2006–2009 saltmarsh survey of England and Wales results with those of Burd (1989). A direct comparison of these results showed an overall increase in saltmarsh extent, but this is not congruent with other reports. Saltmarsh has been reported to be laterally accreting or stable in the Wash (eastern England) (Pye, 1995) and in the Dee and Clwyd estuaries (north-west England) (Dargie, 2000; Huckle *et al.*, 2004). But, significant losses due to erosion have been recently reported in the Solent (Baily and Pearson, 2007; Bray and Cottle, 2003; Cope *et al.*, 2008; Williams *et al.*, 2010) and Greater Thames (south-east England) (Cooper *et al.*, 2001; van der Wal and Pye, 2004).

The Wash. Pye (1995) reported that some of the saltmarshes in the Wash were in a state of dynamic equilibrium or experiencing marginal erosion, but that the majority were still laterally accreting. Since 1950, there has been a major seaward movement of both high and low water mark along the western shore, which has been accompanied by a seaward extension of the saltmarsh. However, the rate of seaward extension has slowed since about 1980. Along the south-western and southern shores, which are most exposed to storm waves, there has been relatively little net change in the position of low water mark during the same time period. There has been only limited seaward growth of saltmarsh at the expense of intertidal mudflats and, in recent years, the seaward edge of these saltmarshes has suffered erosion. In the more sheltered south-eastern corner of the Wash, there has been rapid seaward accretion of saltmarshes since 1950, and despite significant land claim, the extent has been maintained. Based on the analysis of aerial photographs from the Anglian Coastal Monitoring Programme (Environment Agency, 2007b), the Environment Agency (2011) determined the evidence consistently showed saltmarsh accreting at a rate of 62–73 ha per year overall.

Dee and Clwyd estuaries. A field survey by Dargie (2000) showed 2858 ha of saltmarsh in the Dee estuary and 45 ha in the Clwyd estuary compared to 2108 ha and 43 ha respectively reported by Burd (1989). On the English shore of the Dee estuary, the saltmarsh considerably expanded from 1955 to 1975. An analysis of aerial photographs by Huckle *et al.* (2004) revealed a progressive colonization of unvegetated mudflats by lower marsh vegetation types. However, between 1975 and 1997, there was only a slight increase in saltmarsh area, but with an increase in middle and upper marsh vegetation, replacing lower marsh. In a second area of the saltmarsh on the English shore, a different pattern of saltmarsh expansion was observed. The area occupied by saltmarsh continued to increase right up to 1997, with extensive lower vegetation suggesting a process of continuing expansion.

The Solent. In the Solent, saltmarsh loss due to erosion was c. 670 ha between 1971 and 2001, about 40% of the total area present in 1971 (derived from Cope *et al.*, 2008). The extent of loss varies, ranging from about 13% at Pagham Harbour to in excess of 80% at Pitts Deep, Portsmouth and Langstone Harbour. Generally, losses in the eastern Solent have been much higher than in the western Solent, although rates appear to be slowing since 1984. In the western Solent, the rate of loss is linear and does not appear to be slowing. Erosion has manifested itself mainly as lateral retreat of the seawards saltmarsh edge — up to 6 metres per year at Lymington (Gardiner *et al.*, 2007) — and in some areas, by internal dissection of the saltmarsh due to creek widening. There are also small areas of localized accretion reported within the region (Cope *et al.*, 2008; Williams *et al.*, 2010). It is predicted that over the next century, there will be a net loss of 812 ha of saltmarsh (Cope *et al.*, 2008).

Greater Thames. In the Greater Thames, the situation resembles the Solent. Between 1973 and 1998, there has been a net loss of c.1000 ha of saltmarsh in Essex, or 25% of the total area present in 1973, although recent erosion rates (1988-1998) have been slower than previous rates (1973-1988) (Cooper *et al.*, 2001). Erosion has again manifested itself predominantly as lateral retreat of the seawards saltmarsh edge, in some cases by several metres per year, and internal creek dissection (van der Wal and Pye, 2004).

After applying a correction factor to the results of Burd (1989) by expert judgement, the Environment Agency (2011) concluded the saltmarsh rate of change in England and Wales to be between a 1 ha gain and an 83 ha loss per year. By comparison, Pye and French (1993) estimated that in England about 105 ha per year of saltmarshes would be lost due to erosion between 1993 and 2013, mainly in southern and south-east regions, and Lee (2001) predicted losses of 6996 ha in England and Wales due to erosion between 1998 and 2048 (c. 349 ha per year).

2.5 Causes and consequences of erosion

Numerous studies have considered the potential causative factors of saltmarsh erosion (e.g. Bertness *et al.*, 2008; Mason *et al.*, 2003; Paramor and Hughes, 2004; van der Wal and Pye, 2004). Research has focused on the Greater Thames and Solent where the erosion is most significant. The evidence presented here reflects this trend. No research to date has unequivocally identified the source of the problem. An extensive study in the Greater Thames indicated that there may be several physical causes for the erosion of saltmarshes; notably not directly related to sea level rise, but rather to historical land claim and embankment construction, a continuous rise of high and extreme water levels, and changes in the wind-wave climate (van der Wal and Pye, 2004). Erosion has also been attributed to biochemical factors including increased use of agricultural herbicides, increased bioturbation and herbivory, consumer control, and the invasion and subsequent die-back of common cordgrass (*Spartina anglica*).

Sea level rise. Evidence suggests that vertical sediment accretion has been sufficient for saltmarshes to maintain their height in the tidal frame despite relative sea level rise in the Greater Thames (van der Wal and Pye, 2004). The same trend has been reported by Cundy and Croudace (1996) for the Solent. In addition, there is no evidence that regional differences in relative sea-level rise account for the observed spatial variation in erosion in the Greater Thames (van der Wal and Pye, 2004). Nonetheless, whether saltmarshes will continue to keep pace with relative sea level rise (a combination of isostatic rebound and eustatic sea level rise) remains contentious because recently the rate of eustatic sea level rise has been increasing. Global average sea level rose at an average rate of 1.8 mm per year from 1961 to 2003 and 3.1 mm per year from 1993 to 2003. It remains unclear whether the increased rate reflects decadal variation or a long-term trend (IPCC, 2007). The vertical range of a saltmarsh is not only controlled by sea level, but also by tidal range and sediment supply; thus, whether or not a saltmarsh will be sustained in the long-term is dependent upon several, locally varying factors (Wolters, 2006).

Land claim and changes in tidal regime. Historically, extensive areas of intertidal mudflats and saltmarshes have been reclaimed to provide agricultural and horticultural land, with the first uses being grazing, samphire gathering and hay making. More recently, they have been reclaimed for waste disposal and industrial uses, including power stations and port facilities (Table 2.2). It is postulated that an increase in tidal range and current velocities as a result of the narrowing of the intertidal zone by land claim has contributed to saltmarsh erosion, which has been exacerbated by a more or less continuous

Table 2.2 Examples of major areas of saltmarsh reclamation in the UK (adapted from: Doody, 1992; Tubbs, 1981)

Purpose	Location	Area (ha)	Date
Agriculture	The Wash	29,000	since 17th century
		3000	in 20th century
	Severn estuary	c.8000	by the Romans and subsequently
	Humber estuary	4663	17th to mid-19th century
	Essex and North Kent	4340	mainly pre-18th century
	Dee estuary	3160	by 1857
	The Ribble	1960	20th century
	Morecambe Bay	1300	13th to 19th century
	Mersey estuary	492	20th century
	Firth of Forth	250	since 1820
	Firth of Tay	149	in the 19th century
	Nigg Bay	80	in the 19th century
Industry	Teesmouth	>2000	by 1974 for port facilities, oil refineries and a power station
	Southampton Water	1090	19/20th century for docks, waste disposal and power stations

regional increase in high and extreme water levels (van der Wal and Pye, 2004). Other factors, such as mud digging and dredging, are thought to have played a similar, localized role in saltmarsh erosion (van der Wal and Pye, 2004). The situation is further complicated where existing saltmarshes are constrained by embankments, preventing natural landwards migration in response to increases in water level, resulting in 'coastal squeeze' (Figure 2.2).

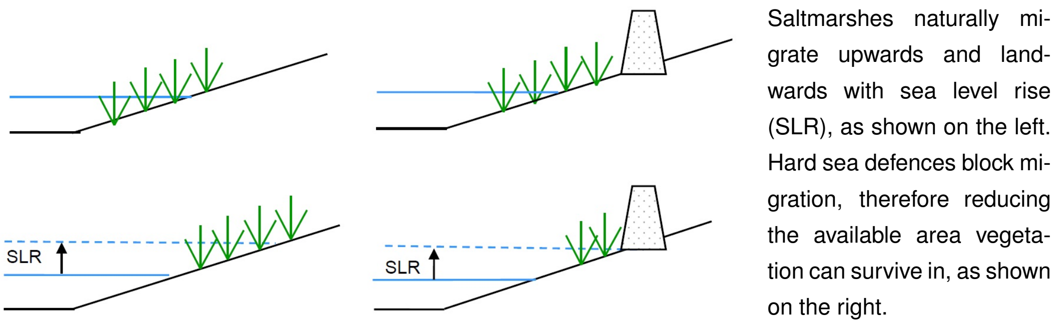

Figure 2.2 Coastal squeeze (Linham and Nicholls, 2010)

Changes in wind-wave climate. A number of studies from the UK and elsewhere show that increased storminess influences vertical and lateral saltmarsh accretion and erosion processes (e.g. Goodbred and Hine, 1995; Pethick, 1992; Stumpf, 1983; Yang *et al.*, 2003). In the Greater Thames, changes in the wind-wave climate correlate with episodes of rapid erosion. For instance, an increase in high magnitude winds and waves since the 1960s, with a peak around 1980, and a high incidence of south-easterly waves between 1976 and 1979, corresponded with the acceleration in saltmarsh retreat as reported for the outer

Thames and Blackwater estuaries, and Dengie and Foulness in this period. Since the late 1980s, rates of saltmarsh loss have decreased in parallel with a decline in overall wind energy (van der Wal and Pye, 2004).

Herbicides. Mason *et al.* (2003) found that herbicide concentrations within the ranges present in the coastal environment have a deleterious effect on diatoms and higher plants both in the laboratory and in the field on the saltmarshes in south-east England. There was qualitative evidence that diatoms migrated deeper into the sediment when the surface was exposed to herbicide, reducing surface sediment stability by the absence of a cohesive biofilm. In addition, sediment loads on leaves severely reduced photosynthesis in sea lavender (*Limonium vulgare*). The study concluded that, coupled with reduced carbon assimilation from the effects of herbicides, this could have large negative consequences for plant productivity and over-winter survival of saltmarsh plants, resulting in increased erosion.

Bioturbation, herbivory and consumer control. Hughes and Paramor (2004) postulated that the increase in the rate of saltmarsh erosion in recent decades was related, at least in part, to an increase in the abundance of the ragworm (*Hediste diversicolor*). In laboratory experiments, *H. diversicolor* consumed and buried seeds and seedlings of glasswort (*Salicornia* species) (Paramor and Hughes, 2004), dwarf eelgrass (*Zostera noltii*) (Hughes *et al.*, 2000) and *S. anglica* (Emmerson, 2000). Thus, bioturbation and herbivory by this species are thought to be responsible for a loss of pioneer plants, increased sediment instability and erosion of saltmarsh creeks (Hughes and Paramor, 2004). But in the absence of published results on increased *H. diversicolor* abundance in south-east England over the last decades, the evidence that this species causes saltmarsh erosion is equivocal (Wolters, 2006). Nevertheless, there is strong evidence from other saltmarsh systems that biological processes can cause erosion. For example, experimental manipulation on saltmarshes in the USA of the dominant grazer (the periwinkle, *Littoraria irrorata*) and its consumers (e.g. blue crabs, *Callinectes sapidus* and terrapins, *Malaclemys terrapin*) demonstrated that plant biomass and production are largely controlled by grazers and their predators. These findings indicate that the high plant production on south-eastern USA saltmarshes is ultimately realized through a trophic cascade, where marine predators limit the densities of plant grazing snails that are capable of denuding marsh substrate (Silliman and Bertness, 2002). Nutrient enrichment has also been shown to induce increased insect herbivory, resulting in suppressed primary productivity in eutrophic saltmarshes by 50–75% (Bertness *et al.*, 2008).

Invasive species. *S. anglica* is a vigorous, pollen-fertile and seed-bearing derivative of the sterile Townsend's cordgrass (*Spartina townsendii*), which itself, is a hybrid of native *S. maritima* and *S. alterniflora*. The latter was introduced by ships in the early 1800s from east North America where it was abundant. In 1892, *S. anglica* was collected at Lymington, in 1893 on the Isle of Wight and from then on with rapidly increasing frequency over a wide area, expanding seawards onto previously bare intertidal mudflats. It has been the major cause of estuarine mud accretion in the southern estuaries of England (Marchant, 1975). It was extensively planted along British coasts to stabilize intertidal mudflats, but became invasive. It has expanded onto beaches at Southport (Ribble estuary) and Cleethorpes (Humber estuary), requiring artificial controls to maintain the beach amenity value (UK National Ecosystem Assessment, 2011a). However, since the 1930s in southern and south-eastern England in particular, die-back of *S. anglica* has occurred for unknown reasons resulting in the erosion of substantial areas of saltmarsh (Townend, 2008).

Regardless of the cause of erosion, the large scale loss of intertidal mudflats and saltmarshes has implications for nature conservation and coastal defence. The observed rates of saltmarsh loss have implications in terms of the direct loss of a nationally scarce natural resource which supports a wide range of flora and fauna (Cooper *et al.*, 2001). There is already good evidence that the loss of intertidal mudflats and saltmarshes has a significant negative impact on birds; adult redshank displaced from Cardiff Bay mudflats following freshwater inundation as a result of barrage construction experienced poor body condition and a 44% increase in mortality rate (Burton *et al.*, 2006). However, the loss of saltmarsh additionally has a wider implication in terms of UK compliance with the Habitats Directive[5] (through the associated UK Habitats and Species Regulations 2010). This implication is of relevance to coastal managers since it must be considered that the loss of such extensive areas of saltmarsh is likely to have significant adverse impacts on the integrity of the internationally designated sites of nature conservation interest (Cooper *et al.*, 2001). In addition, the continued erosion of intertidal mudflats and saltmarshes is likely to result in progressively less wave attenuation over the mudflat-saltmarsh surface, resulting in progressively more direct wave action on the existing coastal defences. The resulting impacts may be manifest through increasing damage to, and maintenance costs of, the coastal defences (Cooper *et al.*, 2001). There are also undoubtedly impacts to the other services provided by intertidal mudflats and saltmarshes (detailed in Appendix A), but there is little evidence to demonstrate specifically how these services will be affected by large scale losses.

[5]Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora

2.6 Responses to loss

Responses congruent with increasing recognition of the importance and value of intertidal mudflat and saltmarshes, and the adverse impacts of their loss, have been typically manifested in a three-tier cascade (UK National Ecosystem Assessment, 2011b) comprising academic research, policy responses and mitigating actions.

As demonstrated by the literature presented in this chapter, the evidence-base supporting the understanding of mudflat-saltmarsh systems, the services they provide and the impacts of their loss is already significant, and continues to grow. It has generated the fundamental knowledge that underpins the legislation and policies that have been enacted and adopted to protect, enhance and restore intertidal mudflats and saltmarshes. However, there are still many unanswered questions, particularly relating to the causes and consequences of recent erosion.

Legislative and policy responses have been an important societal reaction to the loss of intertidal mudflats and saltmarshes. The UK is a signatory to the Ramsar[6], Bern[7], Bonn and Biodiversity Conventions that protect and stimulate actions to maintain or restore the 'favourable' status of intertidal mudflats and saltmarshes. These have been transposed into European and UK policies in a variety of ways (Table 2.3). Meeting legislative and policy obligations has been a major driver of actions to restore or create intertidal mudflats and saltmarsh. For example, the UK Biodiversity Action Plan specifies that it is necessary to maintain the present extent of the UK's intertidal mudflats and saltmarshes. Furthermore, that provision should be made to restore the saltmarsh extent to a 1992 baseline (the year of adoption of the Habitats Directive) (UK Biodiversity Group, 1999). However, legislative protection has also resulted in land-use conflicts which restrict potential actions to restore or create intertidal mudflats and saltmarshes, for example, where trade-offs are required between these habitats or with other habitat types designated for their conservation value, such as coastal grazing marsh (Gardiner *et al.*, 2007).

Numerous attempts have been made to mitigate intertidal mudflat and saltmarsh loss by a variety of methods. The term 'intertidal mudflat and saltmarsh reparation (IMSR)' is introduced here as the general name for all such methods. Since the early 1990s, intertidal mudflat and saltmarsh reparation schemes have contributed to gains in extent in the UK, predominantly for habitat conservation and sustainable flood defence purposes (Dearnley *et al.*, 2007; Rupp-Armstrong and Nicholls, 2007). The main methods used have been the

[6] Convention on Wetlands of International Importance especially as Waterfowl Habitat, ratified in 1976
[7] Convention on the Conservation of European Wildlife and Natural Habitats, ratified in 1982

Table 2.3 Legislation and policies protecting intertidal mudflats and saltmarshes

Convention	European policy	UK policy	Protection method	
Ramsar			Ramsar sites	
Bern	Birds Directive[a]	Wildlife and Countryside Act 1981[b]	Sites of special scientific interest (SSSIs)	
		Habitats and Species Regulations 2010	Special Areas of Protection (SPAs)	Natura 2000
Bonn	Habitats Directive	Habitats and Species Regulations 2010	Special Areas of Conservation (SACs)	
Biodiversity	'Target 2010'	Biodiversity Action Plan	Targets and actions to reduce biodiversity loss	

[a] Directive 2009/147/EC on the conservation of wild birds (codified version of Directive 79/409/EEC as amended)
[b] Wildlife and Countryside Act 1981 c. 69 as amended

managed realignment of coastal defences and the beneficial use of dredged materials.

Managed realignment is the deliberate process of breaching coastal defences to allow flooding of a presently defended area. The process generally involves setting back the line of actively maintained defences to a new line, inland of the original or preferably, to rising ground. This promotes the creation of intertidal habitat between the old and new defences. In most cases, the objective is to create saltmarshes (Linham and Nicholls, 2010). Managing this process helps to avoid uncertain outcomes and negative impacts. It also helps to maximize the potential benefits (Leggett *et al.*, 2004). A number of terms may be used as an alternative to managed realignment. These include managed retreat, dike realignment, dike (re-)opening, de-embankment and de-polderisation (Rupp, 2010).

Dredged materials have been used in the UK for the recharge of existing, impoverished mudflats and saltmarshes and for the creation of new mudflats and saltmarshes, usually where they have previously existed or nearby (Dearnley *et al.*, 2007). Options for use include: (1) direct placement onto intertidal areas (constrained or unconstrained) to raise the elevation relative to the tidal frame and/or to increase the lateral extent; (2) sub-tidal placement at a single point or at a series of points along the shore (called 'trickle charge') or dispersion into the water (called 'water column recharge') to recycle the sediment onto mudflats and saltmarshes by natural hydraulic processes; and (3) direct placement into managed realignment sites to build up the bed level prior to breaching the coastal defences (Dearnley *et al.*, 2007). Three techniques may be used to disperse the dredged materials: pumping via 'rainbowing', which describes the process of sediment placement whereby a special bow jet sprays the sediment onto the shore or into the water with a lateral movement resulting in a rainbow effect; pumping via pipeline, in which sediment may be either pumped from the dredger to the shore via rigid hydraulic pipes or directly into the water from the dredger; and 'grab and place', where placement is accomplished by unloading the sediment mechanically, usually with the same apparatus that was used to dredge the material (Colenutt, 2001; Sloan, 2003). The technique used is often dependent upon the type of dredging plant used, i.e. whether suction or mechanical (Sloan, 2003). Most schemes use fine-grained materials from maintenance dredging of existing ports and navigation channels (Environment Agency, 2007a).

The reparation of intertidal mudflats and saltmarshes via managed realignment and beneficial use of dredged materials delivers environmental, economic and social benefits. It reinstates habitats for specialized flora and fauna, and can significantly reduce the requirements for 'hard' coastal defences, thereby alleviating maintenance costs and increasing the resilience of the coast to future changes. Furthermore, these areas can then be used to promote recreation and tourism (Linham and Nicholls, 2010). For example, a managed realignment project at Alkborough Flats in the Humber estuary (eastern England) created 370 ha of intertidal mudflats, saltmarsh, reedbeds and coastal grazing marsh on formerly agricultural land. In addition to the biodiversity value of the habitats created, the inundation of the site provided a capacity that is sufficient, according to Environment Agency predictions, to reduce high tide levels over a large part of the upper estuary by 100–150 mm, thereby mitigating the climate change impacts of predicted sea level rise for c. 25 years. The project has also provided a focus for 'green tourism' in the area, opening up 8 km of footpaths around the site, many designed for access by people with disabilities. It has been estimated that cumulatively, and relative to the initial £10.2 million investment, the net lifetime benefit-cost ratio is 3.22 based on a very conservative valuation of ecosystem services (Everard, 2009). However, particularly in the case of beneficial use of dredged materials, these practices have generally been limited to relatively small-scale trials (see Appendix B). One of the biggest drawbacks of managed realignment is that land must be yielded to the sea, which requires trade-offs with other land uses. For this reason, managed realignment is often of high political and social controversy. The schemes frequently suffer from a lack of public acceptance, perhaps because of a perceived threat from the sea coming closer or because of a reluctance to lose land which ancestors fought hard to reclaim from the sea. The situation is further complicated by the involvement of numerous land owners (Rupp, 2010). Except where combined with managed realignment, beneficial use schemes do not necessitate land loss, but there are still numerous perceived barriers (Table 2.4).

Aside from the above, evidence suggests that schemes have tended to occur on an *ad hoc*, case by case basis, that is, in response to a specific situation or problem, without considering wider or longer-term issues. For example, Wightlink Limited proposed to recharge 0.3 ha of saltmarsh by direct, constrained placement at Boiler Marsh on the Boldre foreshore, near Lymington (Hampshire) to mitigate for the perceived adverse im-

Table 2.4 Perceived barriers to beneficial use of dredged materials for intertidal mudflat and saltmarsh reparation

Concern	Perceived constraints/barriers
Ecological	Concerns regarding smothering of existing species, increased suspended sediment during placement, and the re-colonization of habitats post-placement (ABP Research, 1999)
	Trade-offs between habitat types may be necessary, e.g. where saltmarsh creation schemes intrude into coastal grazing marshes or other habitats (Fletcher *et al.*, 2001)
Practical engineering and logistical	Schemes must coincide with dredging (Fletcher *et al.*, 2001)
	Dredged materials may be lost from the recharge site (ABP Research, 1999)
	Beneficial use takes longer to plan, obtain permits/licences for, and implement than offshore disposal of dredged materials. Numerous authorities and regulatory bodies may have to be consulted during the process (ABP Research, 1999; Environment Agency, 2007a)
	Dredged materials may vary in quality and quantity, and may be contaminated (Burt and Murray, 2004; Fletcher *et al.*, 2001; Williams *et al.*, 2010)
Financial	Costs for appropriate vessels/plant/machinery, project design, construction and monitoring (Environment Agency, 2007a; Fletcher *et al.*, 2001)
	Funding of a project with uncertainties and scientific unknowns (Fletcher *et al.*, 2001)
Legal	Uncertainty and changing regulations (Fletcher *et al.*, 2001)
Social	Concern that the scheme represents an irreversible change to the natural system (Fletcher *et al.*, 2001)
	Uncertainties in establishing the impacts on the habitat over the life-time of the scheme (Fletcher *et al.*, 2001)
	Dredged materials may be perceived to be contaminated regardless of their actual status (ABP Research, 1999)

pacts of the operations of their new 'W-class' ferries, which operate between Lymington and Yarmouth (Isle of Wight) (ERM, 2010a). The decision-making process was characterized by ongoing conflict between stakeholders, particularly regarding uncertainties in the degree of the impact of the ferries and the practical aspects of the proposed recharge scheme. Thus, obtaining consent for the recharge scheme took almost 5 years. But, even though the recharge scheme has now taken place, it will not, and was never designed to, address the wider saltmarsh degradation and erosion that is occurring in the area. Simulations undertaken for the BRANCH project have shown that by the 2080s, assuming that current coastal defences are maintained, saltmarsh will be completely lost between Hurst Spit and Lymington under all climate change scenarios (BRANCH Partnership, 2007).

By comparison to the UK, larger scale intertidal mudflat and saltmarsh reparation schemes have been implemented in Europe and, in particular, in the USA where, over the past 25 years, the US Army Corps of Engineers (USACE) have developed and improved methods that meet US environmental standards (ABP Research, 1999). So, although the methods and techniques for intertidal mudflat and saltmarsh reparation are relatively novel in the UK, in the majority of cases, they have been tried and tested elsewhere (albeit in a different policy context) (ABP Research, 1999).

2.7 Conclusions

Intertidal mudflats and saltmarshes form a critical interface between marine and terrestrial systems. They are particularly important, and valuable, for nature conservation and for coastal defence. The uncertainties in their current status and trends make it difficult to assess on a UK scale the overall net change in extent. But, it is apparent that despite the implementation of 'no net loss' conservation policies, losses due to erosion continue to exceed gains from intertidal mudflat and saltmarsh reparation schemes in south-east and southern England. IMSR schemes in the UK have been generally limited to relatively small-scale trials in comparison to elsewhere in Europe and in the USA. Numerous studies have considered the potential physical and biochemical causes of erosion, but no study to date has unequivocally identified the source of the problem. Regardless of the cause of the erosion, the loss of intertidal mudflats and saltmarshes has adverse impacts on the provision of the ecosystem services upon which humans and other species depend, and brings into question the UK's compliance with international and national nature conservation legislation and policies.

The evidence presented in this review suggests that to realize the conservation and sustainable use of intertidal mudflats and saltmarshes requires improvements in both knowledge and actions. Science-based research must continue to identify and to better understand the complex links within and between intertidal mudflats and saltmarshes, their rate of change, the causes and consequences of their loss, and the methods for their reparation. There will remain uncertainties, knowledge gaps and controversies in the evidence for the foreseeable future. But, there is already sufficient knowledge to act. Thus, alongside further science-based research, the challenge is to develop a decision-making process capable of accommodating complexity, uncertainty and multiple diverse perspectives, through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken.

Chapter 3

Multi-methodology systems intervention

3.1 Introduction

The development of a plenitude of systems approaches over the past decades opened up the possibility of multi-methodology systems intervention (MMSI). This involves combining systems methodologies, in whole or in part, for the purpose of resolving a problem situation. As noted by Mingers (2003), theoretically, various approaches to combining methodologies have been suggested, and in practice, a range of methodologies are increasingly employed together. Thirty years since MMSI came to the fore, researchers and practitioners remain engaged in discourse regarding the best ways to choose and apply methodologies (see section 3.4 and section 3.5).

This chapter reviews MMSI as a lens through which to view a complex problem situation, and to make decisions and take actions to resolve it. Specifically, it presents the core concepts of systems approaches and their place in decision-making, the development of MMSI theoretically and in practice, and its feasibility and desirability. Finally, it considers possible future developments in MMSI.

3.2 Core concepts of systems approaches

Systems approaches to decision-making are concerned with intervening in a problem situation in order to change it for the better. More specifically, they apply systems thinking in practice to address a problem situation, which encompasses both systemic and systematic thinking and action. These two adjectives are both derived from the word *system*: systemic — pertaining to wholes; and systematic — linear or sequential thinking or action (Ison, 2010).

According to the Open University (2006a), systems thinking is based on the concept that a problem situation, called a *situation of interest*, can be considered as a conceptual system, called a *system of interest*. The constituent parts of a problem situation lie within the boundary of an associated system, and are called *sub-systems*. Everything else is in the system's environment, which surrounds and affects the system, and in most cases, is affected by it, just as in the problem situation. The boundary is not fixed, but identified by the system's observer, and is linked to the system's purpose (Figure 3.1). Identifying the parts within the system, those in its environment and the boundary between the two can be a useful means of identifying what is relevant in a problem situation and what can be changed. Thus, systems thinking in practice can be used to manage situations where there is complexity, confusion or conflict, particularly regarding issues of purpose, function, organization, structures and measures of performance of systems of interest (Open University, 2006b). Ackoff (1974), a widely known systems thinker, called such situations 'messes' and argued that they are not amenable to improvement through thinking which is deterministic or reductionist. There is also rarely a single 'right' solution to a mess.

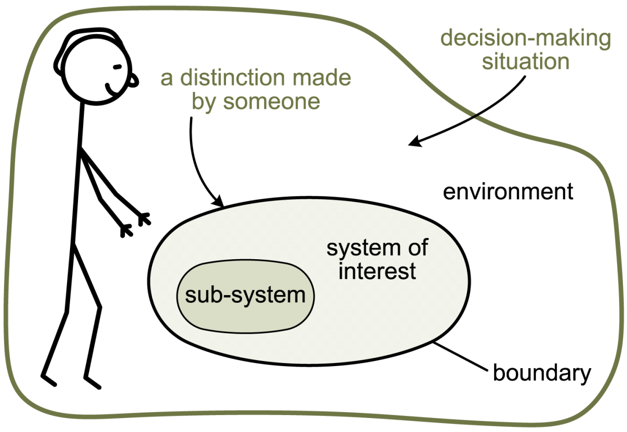

Figure 3.1 Key elements of systems thinking in practice within a decision-making situation (adapted from: Open University, 2006b)

Chapman (2004) asserts that the core aspects of systems thinking are gaining a bigger picture (going up a level of abstraction) and appreciating other people's perspectives of a problem situation. This builds upon the distinction made by Bawden (1998) in identifying two transitions implicit in the history of systems thinking: holism and pluralism. These two transitions counter the traps of conventional thinking — reductionism and dogmatism — respectively. Formalized conventional thinking, such as traditional scientific research, generally seeks to understand and to solve a problem by breaking it down in to consecutively smaller parts. By contrast, systems thinking focuses on resolving (improving) a problem situation by understanding the relationship between the parts, which enables properties to be observed that cannot be found from the properties of the component parts (Reynolds and Holwell, 2010). The skill of systems practice is to use systems thinking as part of a process of learning in which the outcome is some improvement to a situation of interest. The particular form of learning at the core of systems practice is concerned with effective action among stakeholders in 'messy' situations. This involves concerted action or 'social learning' (Open University, 2006b).

3.3 System approaches and decision-making

There is extensive literature about decision-making in relation to problem situations, which reflects both the extent of decision-making processes and the problem situations in which they have been applied (Blackmore and Blackmore, 2007). No attempt is made to comprehensively review the literature here, rather key points are drawn from it in order to contextualize systems approaches in the wider field of decision-making.

March (1994) observes that by far the most common portrayal of decision-making is one that interprets action as rational choice. He states that rational theories of choice assume that decision-making processes are consequential and preference-based: alternatives are interpreted in terms of their expected consequences, then compared in terms of the extent to which their expected consequences serve the preferences of the decision-makers. He goes on to note that some versions of rational choice theory assume that all decision-makers share a common set of basic preferences, that alternatives and their consequences are defined by the environment, and that decision-makers have perfect knowledge of those alternatives and their consequences. Furthermore, that other versions recognize greater inter-actor subjectivity but nonetheless assume perfect knowledge for any particular decision. However, he concludes that pure rationality strains credulity as a description of how decisions actually happen; and as a result, there have been numerous efforts to modify theories of rational choice which maintain the basic structure but revise the key assumptions to better reflect observed behaviours.

In this context, Simon (1957) is purported to have coined the term 'limited (or bounded) rationality'. He recognizes that although decision-makers intend to be rational, they are constrained by cognitive capabilities and incomplete information and thus, their actions may not be entirely rational despite their best intentions. As discussed in section 3.2, faced with the challenges of complexity and uncertainty, problem situations tend to be decomposed into their component parts on the presumption that solving each part individually will result in an acceptable solution to the overall problem situation. In reality, it has been observed that rational decision-making processes may lead to good outcomes, but also that unintended (and often unwelcomed) consequences may emerge (Reynolds and Holwell, 2010).

March (1994) criticizes rational theories of choice because they can fail to take account of what is happening in a problem situation, i.e. it's context. According to Blackmore and Blackmore (2007), a rigorous and logical process of comparison of only some alternatives is likely to reach a 'wrong' decision from the perspectives of the stakeholders in a situation, regardless of how rigorous and logical the process is; and similarly, in complex and dynamic situations in which the alternatives are changing, the consequences are uncertain, and the preferences are not shared by the stakeholders. In their experience, taking account of context in decision-making requires more systemic processes that explore and re-explore the context of a decision from multiple perspectives before and alongside identifying what problems, opportunities and alternatives might be relevant. They conclude, however, that systemic and systematic processes are not mutually exclusive, and that both are ultimately needed. This concept is further explored in section 3.7, which introduces a framework for systemic and systematic decision-making. To reiterate what has been said previously, systems approaches to decision-making — which encompass both systemic and systematic thinking and action — are concerned with intervening in a problem situation in order to change it for the better, and multi-methodology systems intervention offers one way of doing this (section 3.2).

3.4 Theoretical development of multi-methodology

Multi-methodology systems intervention evolved from the development of hard, soft and critical systems approaches by numerous researchers and practitioners since the 1940s.

Von Bertalanffy (1950, 1968), an Austrian biologist, is commonly credited with founding the Systems discipline with the formulation of 'general systems theory' in the late 1940s, after recognizing that ideas about organisms could be extended to complex wholes of any kind. These ideas were subsequently developed into several distinct methodologies, including RAND's systems analysis (Hitch, 1955; Quade, 1963), viable systems model (Beer, 1972, 1979, 1985), system dynamics (Forrester, 1958, 1961, 1969), and systems engineering (Hall, 1962).

In the 1970s, in response to the perceived limitations of 'hard' systems methodologies, particularly with regards to complex management problems, 'soft' systems methodologies came to the fore, most notably including soft systems methodology (Checkland, 1972, 1981, 2000; Checkland and Poulter, 2010; Checkland and Scholes, 1990), strategic assumption surfacing and testing (Mason and Mitroff, 1981; Mitroff and Emshoff, 1979; Mitroff *et al.*, 1979), interactive planning (Ackoff, 1981) and strategic options development and analysis (Eden, 1989). Whereas hard systems methodologies seek to make sense of, or simplify (in *understanding*) the relationships between the parts of a problem situation in which there is consensus regarding the purpose and objectives of intervention and change, the primary strength and focus of soft system methodologies is surfacing and engaging (through *practice*) contrasting perspectives associated with a problem situation. Determining specifically *what* the problem is, *how* and *why* is an acknowledged part of the process (Reynolds and Holwell, 2010).

In the early-1980s, 'critical' systems methodologies emerged, most notably critical systems heuristics (Ulrich, 1983), in response to the perceived need to accommodate emancipatory interests in decision-making. In contrast to both hard and soft systems methodologies, the focus is oriented towards exploring and reconciling (with *responsibility* via the braiding of understanding and practice) power relations and boundary issues associated with a problem situation (Reynolds and Holwell, 2010).

In the mid-1980s, following the advent of critical systems thinking, the focus of systems theory shifted away from developing new methodologies *per se* to developing meta-methodologies, or frameworks for choosing and applying methodologies in practice. Several attempts have been made to address the issue, most notably by Jackson and Keys (1984), Jackson (1987, 1999, 2003), Flood and Jackson (1991), Flood (1995a,b), Midgley (1990, 1997) and Mingers and Brocklesby (1997).

Jackson and Keys (1984) and Jackson (1987) developed a 'system of systems methodologies' to classify methodologies into a grid according to (1) the stakeholders' agreement upon goals: unitary, pluralist and coercive; and (2) the relative complexity of the problem situation: simple or complex. Methodologies were assigned to each of the six possible combinations based on their performance within their own paradigm (Table 3.1). The user decides which methodology from the range of alternatives is most suitable in a given problem situation. As noted by Mingers and Brocklesby (1997), this implies that only one methodology will be used in a particular intervention.

Recognizing the limitations of the system of systems methodologies, Flood and Jackson (1991) and Flood (1995a,b) developed 'total systems intervention', which introduced the concept of using different methodologies within the same intervention to deal with different issues, or to provide different viewpoints (Mingers and Brocklesby, 1997). It comprises three phases of intervention: creativity, choice and implementation (Table 3.2). The set of issues and concerns determined from the 'creativity' phase inform the choice of methodology (or methodologies) in the 'choice' phase, using the system of systems methodologies as a source of knowledge. Jackson (2000) suggests that the most prob-

Table 3.1 System of systems methodologies (adapted from: Jackson, 2000; Jackson and Keys, 1984)

		Participants		
		Unitary	Pluralist	Coercive
Systems	Simple	e.g. systems analysis, systems engineering	e.g. strategic assumption surfacing and testing	e.g. critical systems heuristics
	Complex	e.g. system dynamics, viable system model	e.g. interactive planning, soft systems methodology	none proposed

Table 3.2 Total systems intervention (adapted from: Jackson, 2000)

		Tasks	Tools	Outcome
Phases of intervention	Creativity	To highlight concerns issues and problems	Systems metaphors	Dominant and dependent concerns, issues and problems
	Choice	To choose an appropriate systems-based methodology (or methodologies)	The system of systems methodologies and knowledge of the strengths and weaknesses of different methodologies	Dominant and dependent methodologies chosen for use
	Implementation	To arrive at and implement specific change proposals	Systems methodologies employed according to the logic of total systems intervention	Highly relevant and coordinated change, improving efficiency, effectiveness, ethicality, etc.

Table 3.3 Framework for mapping methodologies (adapted from: Mingers and Brocklesby, 1997)

		Phases of intervention			
		Appreciation of:	Analysis of:	Assessment of:	Action to:
'Worlds'	Social	social practices, power relations	distortions, conflicts, interests	ways of altering existing structures	generate empowerment and enlightenment
	Personal	individual beliefs, meanings, emotions	differing perceptions and personal rationality	alternative conceptualizations and constructions	generate accommodation and consensus
	Material	physical circumstances	underlying causal structure	alternative physical and structural arrangements	select and implement best alternatives

Table 3.4 A possible multi-methodology design according to Mingers and Brocklesby (1997)

		Phases of intervention			
		Appreciation of:	Analysis of:	Assessment of:	Action to:
'Worlds'	Social	Critical systems heuristics and soft systems methodology			
	Personal	Soft systems methodology	Soft systems methodology and cognitive mapping	Soft systems methodology	Strategic choice approach
	Material	Statistics and soft systems methodology		Viable systems model	

able outcome is that there will be a 'dominant' methodology chosen, to be supported if necessary by 'dependent' methodologies in the 'implementation' phase, albeit that the relationship between the dominant and dependant methodologies can be altered as the problem situation changes.

Mingers and Brocklesby (1997) build on the concepts of total systems intervention with the suggestion of a framework for mapping methodologies, and a systematic way of decomposing methodologies into 'detachable elements' such that multiple methodologies can be used, in whole or in part, from different paradigms within an intervention. The framework comprises a grid that can be used to map the characteristics of different methodologies to help to link them together (Table 3.3). As described by Mingers and Brocklesby (1997), the logic of the framework is that a fully comprehensive intervention needs to be concerned with (1) three different 'worlds': material, personal and social; and (2) four different phases of intervention: appreciation, analysis, assessment and action. Thus, each box in the grid generates questions about particular aspects of the problem situation that need to be addressed. It is then possible to look at particular methodologies and see to what extent they address these questions, and appraise their relative strength in each box. The point is not to pigeon-hole a methodology into a particular box, but to look across all the boxes and note all those that a particular methodology may help with (Table 3.4). Figure 3.2 shows an example of the systematic way of decomposing methodologies within a particular intervention proposed by Mingers and Brocklesby (1997). Applying the logic of total systems intervention, this implies that soft systems methodology is the 'dominant' methodology, possibly supported by 'dependent' methodologies — cognitive mapping, critical systems heuristics and viable systems model — at various stages of intervention. However, as noted by Mingers (2003), where methodologies are used out of context, assumptions made about methodologies and the subsequent mapping of them according to the framework for mapping methodologies (Table 3.3) do not apply.

Flood and Romn (1995) use the term 'oblique' to describe the use of methodologies for purposes other than those they were originally designed for. However, Midgley (1997) argues that all the case studies that have been subject to an oblique interpretation can be better explained if they are seen as examples of the 'creative design of methods' (Midgley, 1990). This involves understanding the problem situation in terms of a series of systemically interrelated research questions, each of which might need to be addressed using a different methodology, or part of a methodology. The research questions, and the method design, are not necessarily determined as a complete set in advance but may evolve as events unfold and understandings of the problem situation develop. Midgley (1997, p.

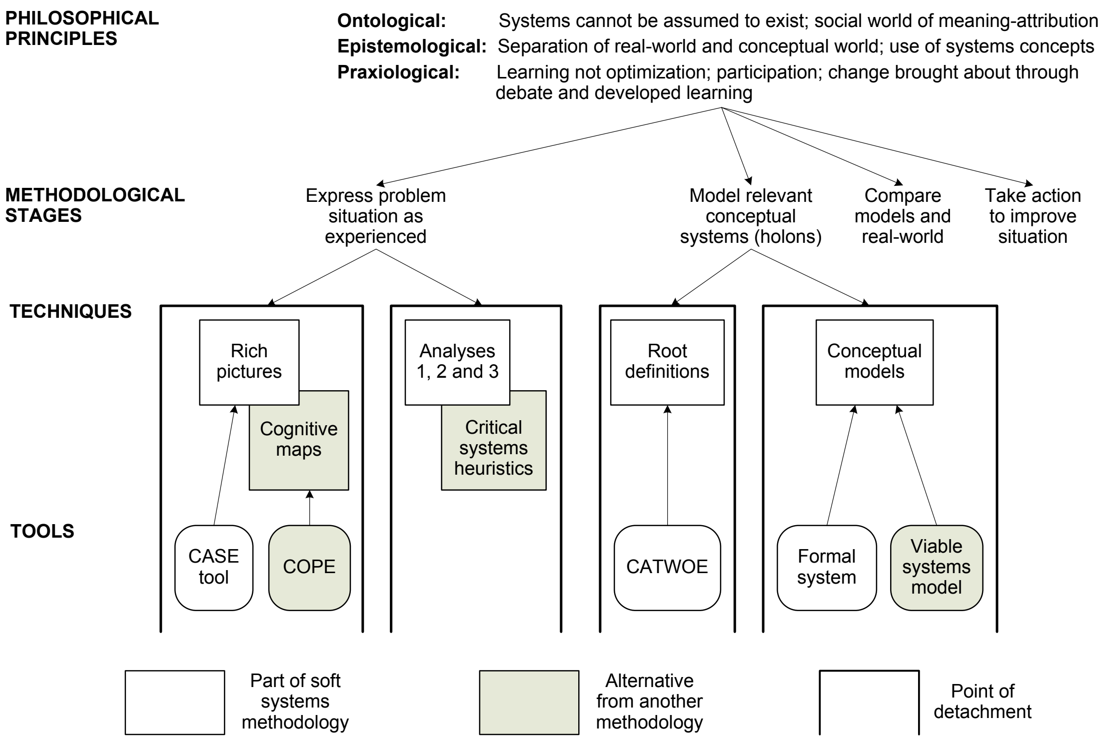

Figure 3.2 A decomposition of soft systems methodology to show possible disconnection of techniques (adapted from: Mingers and Brocklesby, 1997)

307–308) states:

> 'A particularly important idea in the creative design of methods is that the final method to be designed will be different from the sum of its chosen parts. It is not simply a matter of 'stitching' methods together in an additive fashion: a synthesis is generated that allows each individual research question to be addressed as part of a whole system of questions [...] Clearly, the final method that is implemented in an intervention is a product of the choices made by the researcher, usually in interaction with others, but these choices may be the result of either conscious deliberation or intuitive reaction (or a mixture of both) depending on the circumstances.'

By comparison, Jackson (1999, 2003) is concerned at the idea of unreservedly combining methodologies across paradigms because of the significantly different philosophical assumptions that underlie them, arguing instead for an alternative 'coherent pluralism' approach. This involves combining methodologies from within a specified paradigm — hard (functionalist), soft (interpretive), critical (emancipatory) or post-modern — but then using several paradigmatic lenses to get different views of the problem situation. It is applied in the same way as total systems intervention, but with an additional 'reflection' phase to ensure that research, and the generation of new learning, receives the attention it de-serves. Jackson (2003) states that, as with total systems intervention, users should be willing to cycle as many times as necessary around the four phases of 'creativity', 'choice', 'implementation' and 'reflection' to resolve the problem situation.

3.5 Multi-methodology in practice

The application of systems approaches to guide decision-making in relation to problem situations in practice lags behind the use of more traditional scientific approaches (Mingers and Rosenhead, 2004). Nonetheless, the use of multi-methodology in practice is diverse in both context and content as evidenced by empirical surveys of practitioners (Mingers and Taylor, 1992; Munro and Mingers, 2002) and a range of published case studies (Table 3.5).

Mingers and Taylor (1992) surveyed (via questionnaires and interviews) the use of soft systems methodology by Operational Research and Management Science practitioners, primarily in the UK. The main findings in terms of multi-methodology were the large number of respondents who reported the use of soft systems methodology in combination with techniques from different methodologies. Some of these are standard techniques, such as cognitive mapping, others are personal creations about which little is known, such as conceptual rich pictures and personal systems maps. The majority of the additions occurred at the 'rich picture' stage. Some replaced the rich picture, e.g. personal constructs, group mind map, while others complemented it, e.g. cognitive kinetics, rich questions. Mingers and Taylor (1992) note that users brought in aspects from other methodologies because they were already familiar with them, rather than to overcome issues encountered with the application of soft systems methodology.

Munro and Mingers (2002) surveyed (via questionnaires) the use of multi-methodology by Operational Research and Systems practitioners, mainly in the UK. The survey found that combining different methodologies within an intervention is a common occurrence, and perhaps increasingly so. Furthermore, that combining methodologies is generally judged more successful by practitioners (as indicated by scores on a 7-point scale) than the use of a single methodology. The majority of combinations used either hard *or* soft systems methodologies; relatively few combinations used hard *and* soft systems methodologies together. The most common (and successful) combinations usually involved soft systems methodology combined with one or two other methodologies or techniques, including simulation, influence diagrams, strategic choice approach, cognitive mapping, critical systems heuristics, and interactive planning. There were also combinations not including soft systems methodology, especially involving system dynamics, cognitive mapping, influence

Table 3.5 Recent case study examples of methodology design (adapted and updated from: Mingers and Brocklesby, 1997)

Type	Name	Description	Meta-methodology[a]	Paradigms	Methodologies[b] and techniques	Application	Reference
Single methodology	Methodology selection	Selecting a whole methodology as appropriate to a problem situation	System of systems methodologies	Single	SSM	Health	Abad-Corpa *et al.* (2013)
						Information systems	Claudia de Paula Silva and Loureiro (2013)
Multiple methodologies	Methodology combination	Combining whole methodologies within an intervention	Total systems intervention	Single	FMEA, FTA	Information systems	Nakamura and Kijima (2011)
				Multiple	SSM, VSM	Environmental management	Luckett *et al.* (2001)
					SAST, VSM, PSM	Information systems	Pollalis and Dimitriou (2008)
					SSM, SD	Environmental management	Adamides *et al.* (2009)
					SSM, SD	Social security	Rodriguez-Ulloa *et al.* (2011)
					SSM, DES	Health	Holm *et al.* (2013)
	Methodology enhancement	Enhancing a methodology with techniques from another	Framework for mapping methodologies	Single	SSM supported by cognitive mapping (SODA)	Information systems	Siau and Tan (2005)
				Multiple	SSM supported by cognitive mapping (SODA) and sign graph diagrams (SD)	Health	Luckett and Grossenbacher (2003)
	Methodology partition and combination	Partitioning methodologies and combining parts	Creative design of methods	Single	Cognitive mapping (SODA) and analytical hierarchy process (MCDA)	Health	Franco and Lord (2011)
				Multiple	IP, rich pictures and CATWOE (SSM), nominal group technique (SAST), analytical hierarchy process (MCDA), ISM, CSH	Information systems	Petkov *et al.* (2007)

[a] The meta-methodology is stated according to its intended use. In practice, like methodologies, the meta-methodologies have sometimes been applied 'obliquely' in ways other than intended. In some case studies, no meta-methodology is explicitly stated.

[b] soft systems methodology (SSM), strategic assumption surfacing and testing (SAST), interactive planning (IP), multi-criteria decision analysis (MCDA), interpretive structural modelling (ISM), discrete event simulation (DES), critical systems heuristics (CSH), strategic options development and analysis (SODA), viable systems model (VSM), system dynamics (SD), problem structuring methodology (PSM), failure mode effect analysis (FMEA), fault tree analysis (FTA)

diagrams, and strategic choice approach. Munro and Mingers (2002) conclude that the choices about which methodologies to use are affected by the knowledge, experience and skills of the particular practitioner, and to some extent the academic or organizational context, as much as by the nature of the problem situation. However, many users do not consciously reflect on, or articulate, their methodological decisions.

Published papers reporting case studies demonstrate that multi-methodology has been used in the context of general organization, information systems, technology, resources, planning, health services (Mingers, 2000) and environmental management (Paucar-Caceres and Espinosa, 2011). Previous literature reviews by Mingers (2000), Mingers and White (2010) and Paucar-Caceres and Espinosa (2011), and the range of recent case studies shown in Table 3.5, highlight the predominance of soft systems methodology used in combination with other methodologies and techniques. This confirms its strong showing in the previous surveys (Mingers and Rosenhead, 2004). Furthermore, the case studies shown in Table 3.5 illustrate the range of different ways in which methodologies have been combined. Mingers and Brocklesby (1997) summarize that the main distinctions between the different possibilities are: whether more than one methodology is used or not; whether the methodologies used come from the same or from different paradigms; whether whole methodologies are used or parts are taken out and combined; and, in the latter case, whether a single methodology is given overall control or whether the parts are linked to form a new, *ad hoc* multi-methodology. In practice, partitioning and combining methodologies, which is the most complex form of multi-methodology, appears to be less frequently applied than other ways of combining methodologies.

3.6 Desirability and feasibility of multi-methodology

The development of MMSI theoretically and in practice raised questions concerning whether it is desirable and feasible to combine methodologies, in whole or in part, particularly across systems paradigms. There now appears to be general consensus regarding the desirability of multi-methodology, but the debate continues in the context of its feasibility.

The most compelling argument concerning the desirability of multi-methodology is that researchers and practitioners are already combining methodologies in practice to intervene in complex problem situations. To this end, Midgley (1997), Mingers and Brocklesby (1997) and Jackson (2000) assert that different methodologies each focus on different aspects of the problem situation, and thus, multi-methodology is necessary to address the full richness of a complex problem situation. Furthermore, they note that intervention typically proceeds through a number of phases, which pose different challenges for the researcher or practitioner. Their experience has been that methodologies tend to be more useful in relation to some phases than others, particularly as understandings of the problem situation develop, so combining them may yield a better result. However, the use of multi-methodology presents its own problems — philosophically, culturally, psychologically and practically — particularly where combining methodologies from different paradigms is concerned.

Researchers and practitioners are divided in debate concerning combining methodologies from different paradigms within an intervention. Jackson (1999) and others argue that the hard, soft and critical systems paradigms are incommensurable, that is, they are mutually exclusive; it is not possible to simultaneously see the problem situation through more than one paradigmatic lens. By comparison, some researchers, such as de Water *et al.* (2007), argue that paradigms are a social construct, and that the distinction between them is artificial and does not exist in practice.

In the context of cultural and psychological feasibility, Mingers and Brocklesby (1997) are concerned about the extent to which individuals' and organizations' values, beliefs and basic assumptions stand in the way of moving from one paradigm to another, as well as the cognitive difficulties faced by practitioners switching between the different paradigms and methodologies. They state:

> 'While it is by no means impossible to extricate oneself from the constraints imposed by a particular culture, this can present difficulties. Ultimately, it is probably fair to say that the degree of difficulty depends upon the strength of one's attachment to a particular institutionalized 'way of doing things', combined with the strength of one's desire to 'do things differently' [...] In moving from hard to soft systems, the agent has to make a not-insignificant adjustment. Moving from either hard or soft systems to the critical paradigm requires a further transformation (Mingers and Brocklesby, 1997, p. 498).'

The problem of transitioning between paradigms is compounded by multi-methodology practice developing ahead of its theoretical underpinnings (Mingers and Brocklesby, 1997). With the possible exception of soft systems dynamics methodology (a combination of soft systems methodology and systems dynamics proposed by Rodriguez-Ulloa and Paucar-Caceres 2004), no standardized designs for multi-methodology appear to exist, but rather multi-methodology designs specific to each intervention. This is perhaps a result of both the large number of possible ways of combining methodologies, many of which have yet to be explored, and also that no two complex problem situations are exactly alike. In order to deal with them effectively, different combinations of methodologies have been perceived to be necessary. The multitude of possible meta-methodologies proposed by various researchers in response to these problems in order to assist in choosing and linking methodologies further complicates this issue. Nonetheless, it is important to remember that despite all of these problems, the successful use of multi-methodology in practice as evidenced in section 3.5 is testament to the fact that it is ultimately both desirable *and* feasible. The problems associated with combining methodologies, in part or in whole, and possibly from different paradigms may be challenging, but they are clearly not insurmountable.

3.7 Avenues of further development in multi-methodology

As evidenced in this review, much has already been done concerning MMSI, but there are further opportunities for more to be done, both theoretically and in practice. In this section, potential avenues of further development in MMSI are considered, including discussion of a framework for structuring and organizing intervention and change in a problem situation.

Intervention and change in problem situation is a result of the dynamic relationship between: (1) the perceived problem situation; (2) theories or frameworks of ideas, e.g. meta-methodologies and methodologies; (3) methods of applying the theories to the problem situation, e.g. interviews and workshops; and (4) the users of the method, e.g. researchers and practitioners (Figure 3.3) (Blackmore *et al.*, 2007; Checkland, 1985, 2000). Ultimately, the success of intervention and change in a problem situation, incorporating the use of appropriate frameworks to investigate and analyse a problem situation, and the use of appropriate techniques and tools to support analysis and decision-making, is dependent upon the users in the context of the problem situation, and in particular, the users' knowledge and experience of the range of different systems approaches available.

With the above in mind, if systems approaches are conceptualized as existing within a systems meta-paradigm[1] (or toolbox) containing the set of methodologies, techniques and tools available to the researcher and practitioner, the issue becomes not one of developing meta-methodologies or 'rule books' which define how these may be used in practice, but rather in educating potential and existing users with the knowledge and experience of an

[1] A meta-paradigm represents the worldview of a discipline. It sets forth the major concepts that distinguish a discipline and establish its boundaries and limitations. The term is commonly used in nursing. See for example: Daniels *et al.* (2009); Fawcett and Desanto-Madeya (2012); McEwen and Wills (2007).

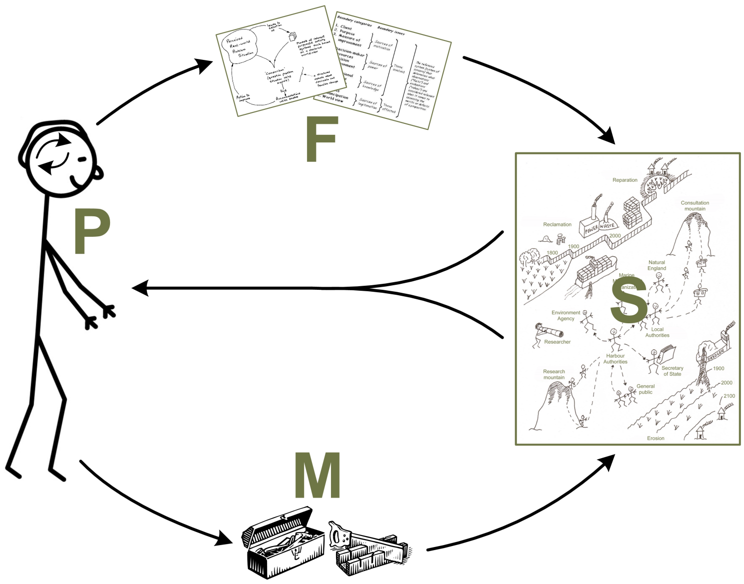

Figure 3.3 A conceptual model of the relationship between a problem situation (S), framework of ideas (F), method (M) and practitioner (P) (adapted from: Ison, 2010)

adequate range of methodologies, techniques and tools such that they can choose appropriately from the systems toolbox for any given problem situation. In this latter respect, the Open University are perhaps leading the field with their framework for environmental decision-making (EDM).

The EDM framework has four linked stages (Figure 3.4) which are broadly consistent with the phases of intervention identified by Mingers and Brocklesby (1997) in the framework for mapping methodologies (Table 3.3). Similarly, as with total systems intervention and the 'coherent pluralism' approach, the cyclic nature of the EDM framework indicates that not only is there interaction between the different stages, but also that it is designed to be used iteratively (Open University, 2007b). But, in contrast to the meta-methodologies previously described in section 3.4, its overall purpose is to provide a structure (rather than a way of choosing and linking methodologies) to enable decision-making to be a process of learning that allows for continuous improvement rather than a one-off, constrained activity that stops once a decision is made (Open University, 2006a). The aim is to use techniques and to develop skills and understanding in systems thinking, modelling, evaluating and negotiating in order to explore the situation, formulate problems and opportunities, identify feasible and desirable changes, and take informed actions. Students learn how to operate the EDM framework — systematically, systemically and critically — via relevant case studies, such as aviation expansion in south-east England (Open University, 2006a), which introduce and illustrate the use of a variety of systems methodologies, techniques and tools at appropriate points in relation to the stages of the EDM framework as discussed in the course textbooks.

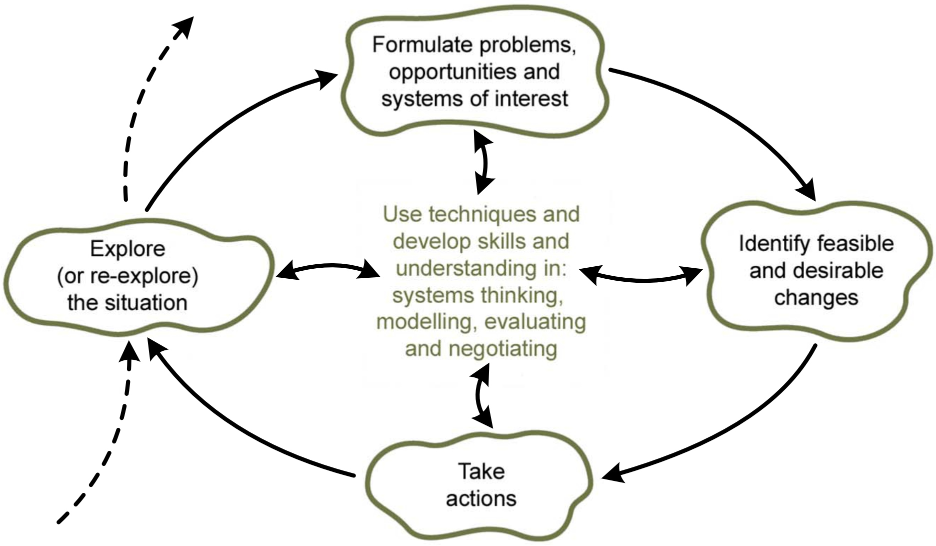

Figure 3.4 Framework for environmental decision-making (adapted from: Open University, 2006a)

The EDM framework was developed originally in 1997 in response to the perceived need to incorporate economic, social *and* environmental issues on an *equitable* basis in decision-making concerning sustainable development. It was revised to its current format in 2006 for the distance learning course entitled *T863 Environmental decision making: a systems approach* to reflect the collective learning of students and the course team about environmental decision-making (Blackmore and Morris, 2001; Ison *et al.*, 2006). Despite its longevity, there are no known published papers reporting case studies which employ the EDM framework in practice. However, Morris *et al.* (1999) and Blackmore and Morris (2001) reviewed how the EDM framework has been used by students for their end-of-course project, and surveyed the perceived effectiveness of how it has been used from both the students' and tutors' perspectives. The problem situations chosen by students ranged from personal to international issues. Most students had a formal, active role within their chosen problem situation, which reflects the number of students who were taking the course for professional or other job-related reasons. The projects were classified according to their starting and end points, into those which began based on historical material, those which began as an 'objective' analysis of an ongoing situation, those where the student was an active participant in such a situation, and those where some proactive, design process was involved. Working with the EDM framework in their projects appeared to move students from *post hoc*, or passive, analyses at the beginning of their projects to more active categories of involvement at the end. It is reported that two-thirds of the students surveyed claimed that the use of the EDM framework either had encouraged them to widen the boundaries of their analysis or had enhanced their understanding of their chosen problem situation. Blackmore and Morris (2001) conclude that in general, the students' own assessment of the effectiveness of the way they had used the EDM framework correlated with those of the tutor who reviewed their project, suggesting that significant learning had occurred.

The EDM framework is not known to have featured previously in the debate concerning multi-methodology despite advocating the use of both systemic and systematic thinking and action, as well as the use of a combination of soft, hard and critical systems approaches, rather than just one or another (Blackmore and Morris, 2001). It has perhaps been hindered in the past in this respect by its explicit focus on *environmental* decision-making. But, applying the broadest definition of the term environment — that which surrounds and affects us and is affected by us — it is more widely applicable to complex problem situations of all types rather than only to those previously categorized as environmental in context. Furthermore, given the synergies between the EDM framework and the meta-methodologies for choosing and linking methodologies described in section 3.4, not least in terms of the phases of intervention and the cyclic, iterative process of decision-making, there is significant scope for it to feature more prominently in the future of MMSI as a guide to structuring and organizing intervention and change in complex problem situations; and where perceived necessary by the researcher or practitioner, used in combination with other meta-methodologies which provide sources of knowledge for choosing and linking methodologies at the various stages of intervention.

3.8 Conclusions

Multi-methodology systems intervention involves combining systems approaches, in whole or in part, for the purpose of resolving a complex problem situation. Systems approaches seek to resolve a problem situation by understanding the relationship between its parts, which enables properties to be observed that cannot be found from the properties of the component parts individually. They counter the traps of conventional thinking — reductionism and dogmatism — via holism and pluralism respectively.

Since the mid-1980s, following the advent of critical systems thinking, several attempts have been made to address the issue of choosing and applying multiple methodologies within an intervention, but no research to date has unequivocally resolved this issue. In practice, multi-methodology systems intervention is diverse in both context and content, with a variety of systems approaches being frequently employed in combination as a whole or in part. However, the use of multi-methodology presents its own problems to researchers and practitioners — philosophically, culturally, psychologically and practically — particularly where combining methodologies from different paradigms is concerned. Nonetheless, there is evidence that multi-methodology systems intervention is ultimately both desirable and feasible in many situations.

Potential avenues for further development in multi-methodology systems intervention have been suggested that emerge from this discussion, including: (1) the concept of a systems meta-paradigm, and its implications for educating potential and existing users with the knowledge and experience of an adequate range of methodologies, techniques and tools such that they can choose appropriately from the systems 'toolbox' for any given problem situation; and (2) an iterative framework for structuring and organizing intervention and change in a complex problem situation that is compatible with existing meta-methodologies for choosing and linking methodologies, such as Mingers' framework for mapping methodologies. Whether these avenues of further development become well-trodden, or remain 'the road not taken' is a matter for future research and debate.

Part III

Data, methods, results and discussion

Chapter 4

Research, policy and practice for the conservation and sustainable use of intertidal mudflats and saltmarshes[1]

4.1 Introduction

Chapter 2 identified that improvements in both knowledge and actions are required to realize the conservation and sustainable use of intertidal mudflats and saltmarshes in the UK. Specifically, there is a need to develop an improved decision-making process capable of accommodating complexity, uncertainty, change and multiple diverse perspectives, through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken. But, in the absence of known research in this field, what might constitute an improvement is questionable because there is a lack of clarity regarding explicitly what the current decision-making process is, and thus, how to intervene to change (improve) it.

The research presented in this chapter addressed the knowledge gap by exploring the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent, where intertidal mudflat and saltmarshes loss is widespread and advancing (see section 1.3). The objective of the research was to observe, describe and develop an empirical overview of the events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes from the perspective of those involved, in order to establish *what* is actually happening, *why*, *how*, and by *who*. It is only once these facts have been established that intervention (or change) in the decision-making process can be conceived; otherwise, there is a danger of falling into the trap of making hasty, and possibly incorrect assumptions about what might constitute improvement.

The research captured a representative snapshot of intertidal mudflat and saltmarsh conservation and sustainable use in the Solent from 1800 to 2016 in the form of a timeline of events. This chapter describes the construction of the timeline, and discusses its

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outcomes and implications.

4.2 Data and methods

The construction of a timeline facilitated collating, consolidating and unravelling the complexities of the events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent, especially in terms of identifying the interconnections between the events, the people who undertake them, and their purpose. The timeline was constructed via an iterative method comprising literature review in combination with a series of semi-structured interviews and email/telephone communications with a range of local stakeholders (Figure 4.1).

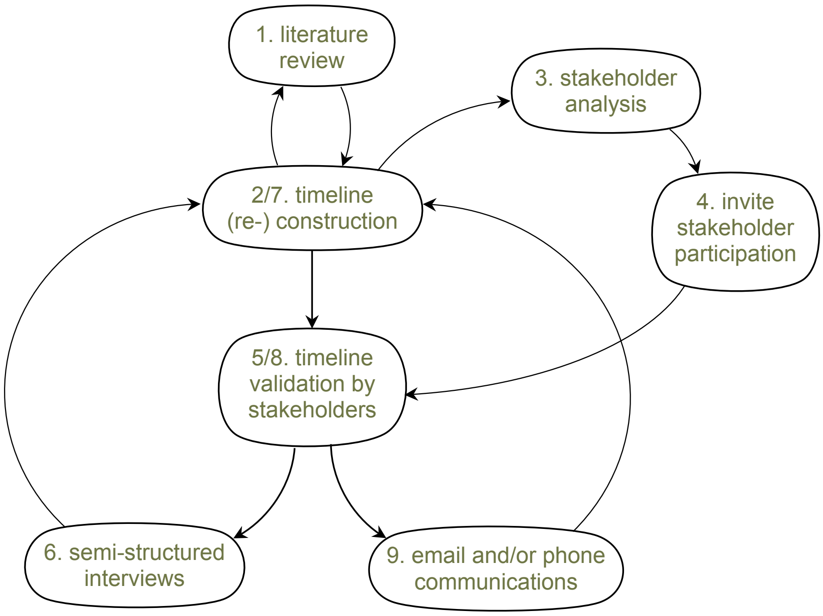

Figure 4.1 Timeline construction method. Steps 1–2 and 7–9 were iterative, and continued until no further amendments to the timeline were required.

Primary sources for the literature review included peer-reviewed research, conference proceedings, technical reports, and books (or sections thereof) that describe the history of the Solent (see Appendix A). The sources were mainly identified via online databases (e.g. ScienceDirect, Google Scholar, WorldCat) and search engines (e.g. Google) using key words including *mudflat*, *saltmarsh*, *conservation*, *sustainable use*, *Solent* and *UK*, as well as specific terms such as *Marsh Improvement Act 1944*. Sources were also identified by manually searching reference lists of known sources and local/national libraries. Additional sources were suggested or provided by local stakeholders (Table 4.1). Each source was manually searched in order to identify relevant events. The sole criterion for the inclusion of an event in the timeline was that it must be perceived to directly or indirectly influence the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent in terms of research, legislation and policy, or practice.

Table 4.1 Stakeholders involved in the construction of the timeline

Organization	Name	Role
Natural England	Graham Horton	Marine lead adviser, southern seas team
Environment Agency	Adam Cave	Biodiversity technical specialist, Solent fisheries and biodiversity team
New Forest District Council / Channel Coast Observatory	Andrew Colenutt	Coastal projects officer, North Solent Shoreline Management Plan project manager
ABPmer	Colin Scott	Managed realignment and EIA specialist
	Susanne Rupp-Armstrong	Marine environmental consultant
University of Southampton	Simon Bray	Visiting research fellow
Retired	Jack Coughlan	Ex-marine biologist for Central Electricity Generating Board, and ex-Hampshire and Isle of Wight Wildlife Trust trustee

The timeline was fed back to stakeholders for validation or refinement. The stakeholders included representatives from central government bodies, local authorities, regulators, consultants, nature conservation groups and academic institutions (Table 4.1). These stakeholders were identified by stakeholder analysis, and chosen specifically on the basis that: (1) as a group, they represent a diverse range of perspectives concerning the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent; and (2) as individuals, they have the local knowledge and experiences to be able to identify errors or omissions in the timeline. The number of interviews and the selection of stakeholders was thus strategic to achieving the research objectives. The stakeholders' assistance was invaluable in validating the timeline presented in section 4.3, which has been amended from previous versions based on their collective input. During the semi-structured interviews, stakeholders were given the opportunity to talk freely about their own role and the role of their organization in the study context, and the events that they perceived to be important, in particular, regarding the representation of these events in the timeline. The subsequent email and/or telephone communications served to re-validate or further refine the timeline as appropriate.

The research method — incorporating literature review with stakeholder feedback in the construction of a timeline — does not guarantee authenticity, but rather serves to decrease the incidence of incorrect data, or the incorrect interpretation of data. It ensures that the issue of intertidal mudflat and saltmarsh conservation and sustainable use in the Solent is explored through a variety of lenses, which allows multiple facets of the situation to be revealed and understood (Baxter and Jack, 2008); and the converging lines of evidence (data triangulation) add strength to the findings (Yin, 2009). However, it should be borne in mind that the findings are inherently more certain for events within living memory of those involved in the study.

Previous case studies have endeavoured to reconstruct other environmental decision-making processes using a combination of sources including literature review and interviews (e.g. Alphandery and Fortier, 2001; Apostolopoulou and Pantis, 2009; Beunen and de Vries, 2011), but there is no known precedent for the use of timelines in these studies. Timelines have been used previously as a tool for conducting life history research (e.g. Adriansen, 2012; Resh and Rosenberg, 2010), and by The Open University, who constructed a simple timeline as the basis for further studies in their distance learning course *T863 Environmental decision-making: a systems approach* (Open University, 2006a). It is the latter which particularly inspired the construction of a timeline to visualize the interconnectedness of events in this study.

4.3 Results and discussion

Figure 4.2 shows an abridged timeline of past, present and future events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from 1800 to 2016. An unabridged version is given in Appendix A. The time period covered by the timeline was a consequence of the dates of known events rather than intentionally chosen cut-off points. The following sections describe the outcomes and implications of the timeline in terms of research, legislation and policy, and practice. As shown in the timeline, events influence and are influenced by other events. The distinction made between the categories of events in the following sections is solely for the purpose of facilitating the interpretation and discussion of the timeline.

4.3.1 Research

Research studies have generally aimed to understand, and to develop methods of addressing where necessary, the causes and consequences of physical and biochemical changes in intertidal mudflats and saltmarshes in the Solent. The studies have produced extensive literature. This research makes no attempt to comprehensively review all of the relevant literature, but it highlights the perceived landmarks and trends in these studies in the context of intertidal mudflat and saltmarsh conservation and sustainable use in the Solent.

The earliest known studies of relevance to this research focused almost exclusively on the introduction, colonization and subsequent die-back of *Spartina* cordgrass, which has

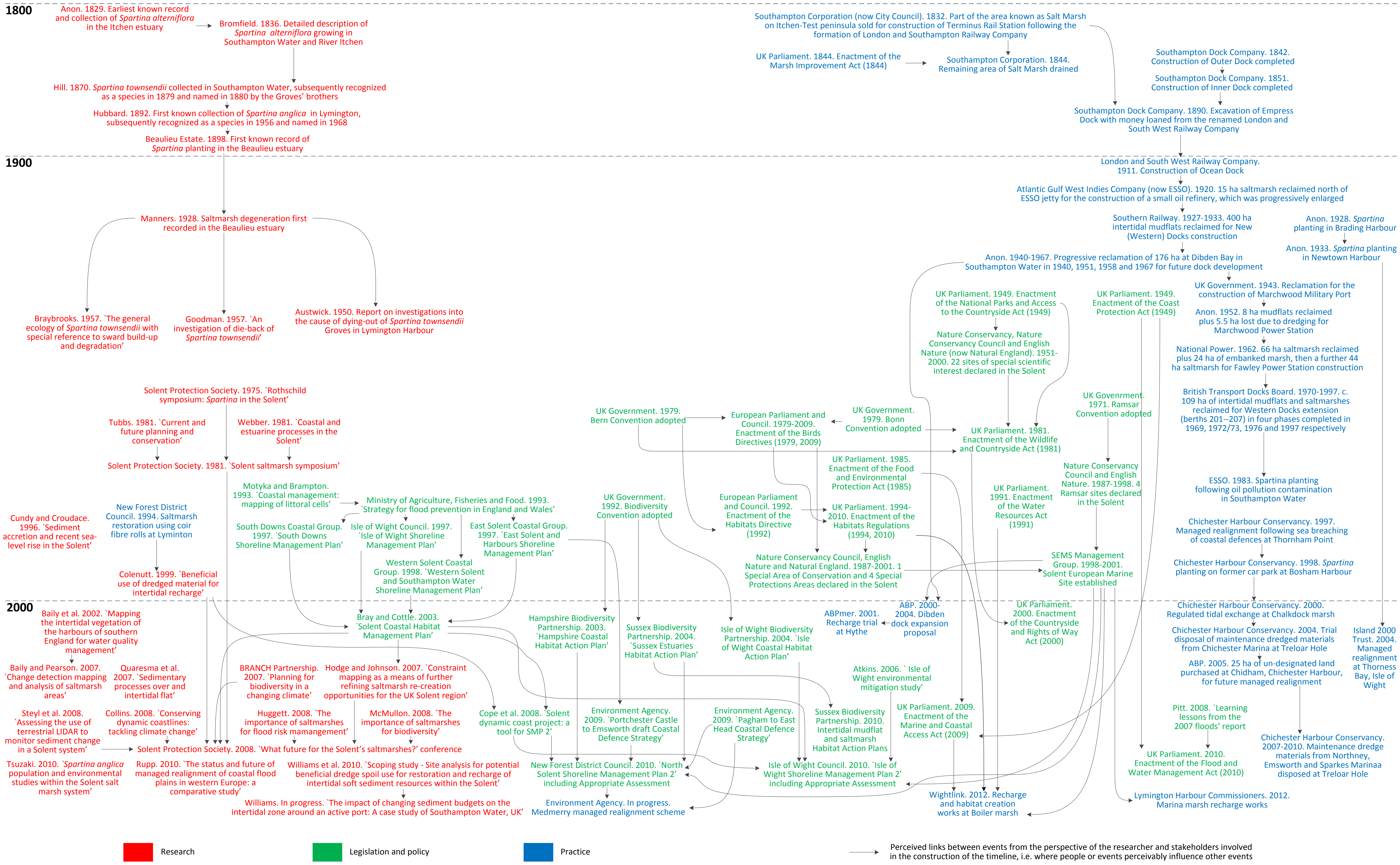

Figure 4.2 Abridged timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from 1800 to 2016. Past, present and future events are shown chronologically so far as is reasonably practicable.

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been the dominant cause of naturally occurring saltmarsh expansion and recession across the Solent since the 1800s. The most notable of these studies include:

- reference to the earliest known British record and collection of *S. alterniflora* (introduced by ships from east North America) in the River Itchen in 1829 (Jacquet 1949 cited in Marchant 1967), and a detailed description of the species growing in Southampton Water and the River Itchen (Bromfield, 1836);
- first known collection of *S. townsendii* (a sterile hybrid of native *S. maritima* and *S. alterniflora*) at Hythe in Southampton Water by Mr RS Hill in 1870 (Stapf, 1913), and its subsequent recognition as a species in 1879 and naming in 1880 by Groves and Groves (1879, 1881, 1882);
- first known collection of *S. anglica* (a fertile derivative of *S. townsendii*) in Lymington in 1892, and then on the Isle of Wight in 1893, and its subsequent recognition as a species in 1956 and naming in 1968 by Hubbard (1957, 1968); and
- investigations into the die-back of *S. townsendii* (Austwick, 1950; Braybrooks, 1957; Goodman, 1957) and *S. anglica* (Tsuzaki, 2010).

From the 1980s onwards, the research scope appears to have broadened to incorporate a much wider range of issues concerning the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent, including:

- conference papers emphasizing the importance and value of intertidal mudflats and saltmarshes in the Solent for biodiversity (McMullon, 2008) and coastal flood risk management (Huggett, 2008b);
- investigations into coastal and estuarine processes, such as sediment dynamics (e.g. Cundy and Croudace, 1996; Quaresma *et al.*, 2007; Webber, 1981; Williams, in progress);
- investigations into methods for mapping intertidal mudflats and saltmarshes in the Solent using photogrammetric techniques (Baily *et al.*, 2002), aerial photography (Baily and Pearson, 2007), and terrestrial light detection and ranging (LiDAR) (Steyl *et al.*, 2008);
- numerous studies extensively exploring the opportunities and impacts of the reparation of intertidal mudflats and saltmarshes across the Solent via managed realignment (e.g. Cope *et al.*, 2008; Hodge and Johnson, 2007; Rupp, 2010) and, to a

lesser extent, the beneficial use of dredged materials (e.g. Colenutt, 1999; Williams *et al.*, 2010); and

- studies addressing the implications and conflicting requirements for intertidal mudflat and saltmarsh conservation and sustainable use in the context of climate change and spatial planning (e.g. BRANCH Partnership, 2007; Bray and Cottle, 2003; Collins, 2008; Tubbs, 1981).

Most recently, the research presented in this chapter brings to the fore the issue of decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent. It drew heavily upon previous relevant research for the purpose of constructing and interpreting the timeline of events.

The significant majority of the research discussed in this section has been conducted by the University of Southampton, but there have also been significant studies by University of Portsmouth, Channel Coast Observatory, and New Forest District Council, amongst others. The research has been periodically brought together in three conferences organized by the Solent Protection Society in 1975, 1981 and 2008, which focused specifically on saltmarshes in the Solent. However, to reiterate the findings of chapter 2, no research to date has unequivocally identified the causes of intertidal mudflat and saltmarsh erosion, which continues unabated across the Solent and elsewhere in the UK, with likely significant, but uncertain implications to the well-being of humans and other species. Further research is still required in order to identify and to better understand the complex links within and between intertidal mudflats and saltmarshes, their rate of change, the causes and consequences of their loss, and the methods for their reparation.

4.3.2 Legislation and policy

Legislation and policy falls into three categories according to whether it promotes (1) reclamation or (2) reparation of intertidal mudflats and saltmarshes, or (3) otherwise influences their conservation and sustainable use.

The earliest known legislation of significance to intertidal mudflats and saltmarshes in the Solent is the Marsh Improvement Act 1844. The local Act permitted the reclamation and development for anthropogenic purposes of an area known as Salt Marsh, comprising about 6.5 hectares of saltmarsh between Terminus Rail Station and the Woolston–Southampton floating bridge (now the Itchen bridge) (The National Archives, 2013). This appears to have cemented a trend for reclamation, resulting in a cascade of events that successively reclaimed vast areas of intertidal mudflats and saltmarshes across the Solent until the mid-1970s (see subsection 4.3.3).

The cease in reclamation practice in the mid-1970s is consistent with the increasing recognition of the importance and value of biodiversity to human well-being, and the subsequent adoption of international nature conservation agreements, including the Ramsar, Bern, Bonn and Biodiversity Conventions, which give rise to UK national legislation and policies relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent.

The Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat was adopted by the UK in 1971 and ratified in 1976. It provides the framework for national action and international cooperation for the conservation and 'wise use' of wetlands and their resources. There are four designated Ramsar sites of significance to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent (Figure 4.3).

The Bern Convention on the Conservation of European Wildlife and Natural Habitats was adopted by the UK in 1979 and ratified in 1982. The principal aims are to conserve and to protect wild species and their natural habitats (listed in Appendices I and II of the Convention), to regulate the exploitation of species (listed in Appendix III of the Convention), and to promote cooperation between contacting parties to this end. The Bonn Convention on the Conservation of Migratory Species of Wild Animals was adopted by the UK in 1979 and ratified in 1985. Contracting parties are required to work together to conserve migratory species and their habitats by providing strict protection for endangered migratory species (listed in Appendix I of the Convention), by adopting multilateral agreements for the conservation and management of migratory species which require or would benefit from international cooperation (listed in Appendix II of the Convention), and by undertaking cooperative research activities. In the UK, the legal requirements of the Bern and Bonn Conventions were implemented by the Wildlife and Countryside Act 1981 (as amended). There are 22 Sites of Special Scientific Interest (SSSIs) designated under this Act relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent (Figure 4.4). The majority of these sites were previously designated SSSIs under the UK National Parks and Access to the Countryside Act 1949. Later, the protection of SSSIs was further strengthened by the enactment of the Countryside and Rights of Way (CRoW) Act 2000. In the EU, the legal requirements of the Bern and Bonn Conventions were transposed into legislation by the Birds Directive and the Habitats Directive. These Directives provided for the establishment of a network of Natura 2000

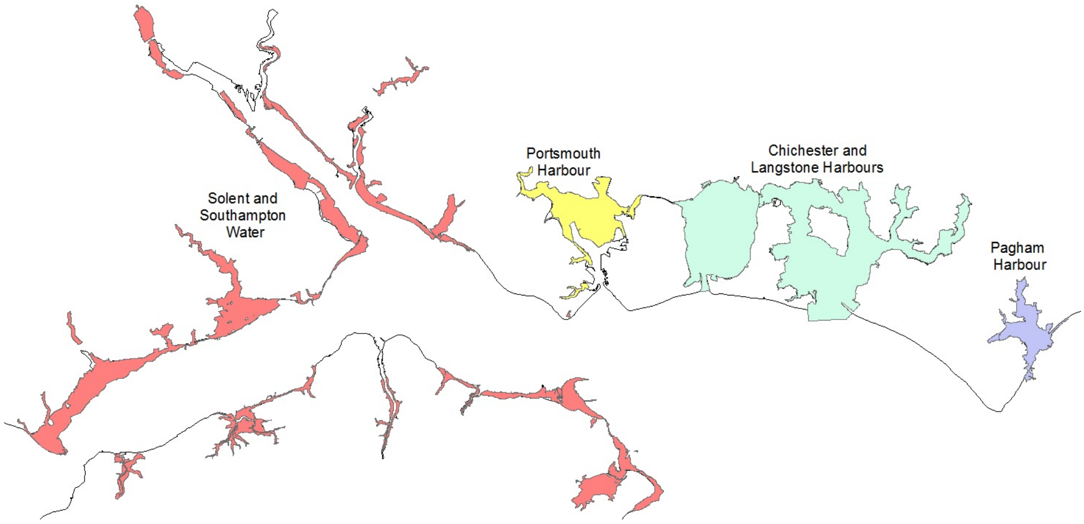


Figure 4.3 Intertidal mudflat and saltmarsh Ramsar and SPA designations in the Solent (boundaries marginally vary between Ramsar and SPA in some locations)

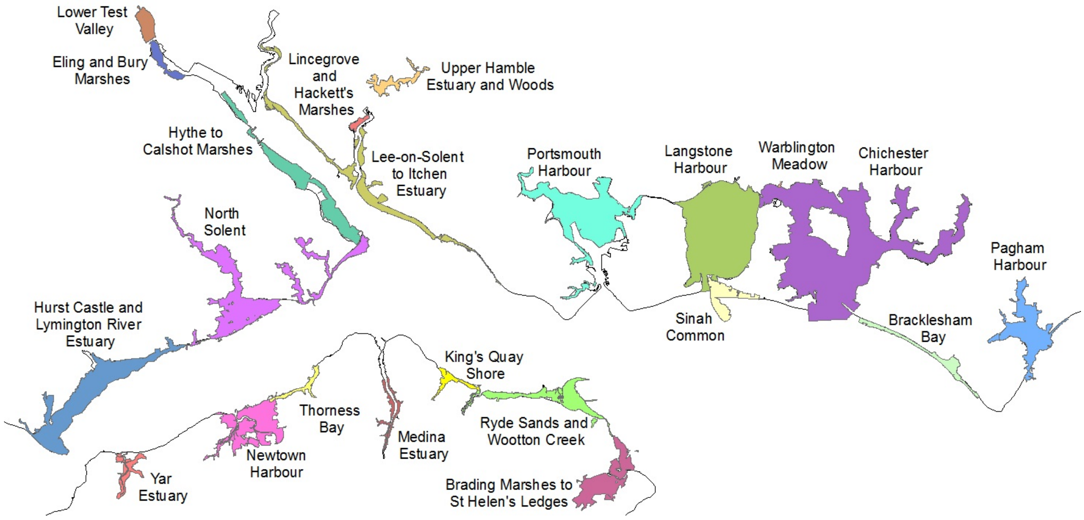


Figure 4.4 Intertidal mudflat and saltmarsh SSSI designations in the Solent

Figure 4.5 Intertidal mudflat and saltmarsh SAC designations in the Solent

sites, comprising Special Protection Areas (SPAs) designated under the Birds Directive and Special Areas of Conservation (SACs) designated under the Habitats Directive. The Conservation (Natural Habitats, &c.) Regulations 1994 (subsequently consolidated into the Conservation of Habitats and Species Regulations 2010) were introduced in the UK to implement the parts of the Directives not already covered in national legislation. There is one SAC designated site (Figure 4.5) and four SPA designated sites (Figure 4.3) relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent. These designations in particular have had significant implications in the context of practice to conserve and sustainably use intertidal mudflats and saltmarshes across the Solent (see subsection 4.3.3).

The Convention on Biological Diversity was adopted by the UK in 1992 and ratified in 1993. The Convention provides a framework for the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of the benefits arising from the use of genetic resources. Contracting parties are required to create and enforce national strategies and action plans to conserve, protect and enhance biodiversity. To this end, the UK introduced non-statutory Biodiversity Action Plans, which specify 'no net loss' targets for intertidal mudflats and saltmarshes. Objectives and proposed actions to meet the targets for the Solent region are set out in the local Coastal Habitat Action Plans for Hampshire (Hampshire Biodiversity Parnership, 2003), Sussex (Sussex Biodiversity Partnership, 2010a,b) and the Isle of Wight (Isle of Wight Biodiversity Partnership, 2004).

Other legislation and policies of significance to this research relate predominantly to coastal flooding and erosion risk management, which influence the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent via the undertaking of capital and maintenance coastal flood and erosion risk management works. The Coast Protection Act 1949 established the legal framework for coastal erosion protection in the UK. It provided Local Authorities with permissive powers to undertake coastal erosion protection works on their own frontage, and to control third party activities, such as the construction of private coastal defences or the removal of beach material (Environment Agency, 2010b). Similarly, the Water Resources Act 1991 provided the Environment Agency with permissive powers to undertake coastal flood defence works in the UK. Following Sir Michel Pitt's Review of the UK floods in 2007 (Pitt, 2008), the Flood and Water Management Act 2010 was enacted to create a simpler and more effective means of coastal flood and erosion risk management. The Act makes provision for the Environment Agency to undertake all coastal flood and erosion risk management works. Local Authorities may undertake coastal flood and erosion risk management works with the Environment

Agency's consent (Environment Agency, 2010b).

Non-statutory Shoreline Management Plans, Coastal Defence Strategies and Schemes respectively set out in broad terms the coastal flood and erosion risk management policies for the next 100 years, identify the preferred options to deliver the policies, and define and implement the preferred options in practice via coastal flood and erosion risk management works. Shoreline Management Plans were introduced by the Ministry of Agriculture, Forestry and Fisheries (MAFF, now DEFRA) in 1993 following the publication of a report by Motyka and Brampton (1993) setting out the advantages of considering the coast in a more holistic and strategic way on the basis of littoral sediment cells (Environment Agency, 2010b). The first generation of Shoreline Management Plans in the Solent (littoral sediment cell 5) were published in 1997 and 1998 (East Solent Coastal Group, 1997; Isle of Wight Council, 1997; South Downs Coastal Group, 1997; Western Solent and Southampton Water Coastal Group, 1998). Coastal Habitat Management Plans were subsequently introduced to provide a framework to fulfil the UK Government's obligations to conserve and protect Natura 2000 and Ramsar sites located on or adjacent to dynamic coastlines (Environment Agency, 2010b). The Solent Coastal Habitat Management Plan quantified changes in the extent of intertidal mudflats and saltmarshes across the region, and recommended measures to prevent future losses (Bray and Cottle, 2003). The findings were verified and updated by the Solent Dynamic Coast Project (Cope *et al.*, 2008) and the Isle of Wight Mitigation Strategy (Atkins, 2006). Revised coastal flood and erosion risk management policies were subsequently set out in the second generation Shoreline Management Plans for the North Solent (New Forest District Council, 2010) and Isle of Wight (Isle of Wight Council, 2010) based on the respective findings of these studies as well as the findings of draft and approved Coastal Defence Strategies for the region developed under the first generation Shoreline Management Plans. The most significant outcomes in the context of intertidal mudflat and saltmarsh conservation and sustainable use in the Solent include:

- justification of potential significant damage to Natura 2000 and Ramsar designated intertidal mudflats and saltmarshes from 'coastal squeeze' due to the implementation 'hold the line' policies in the North Solent Shoreline Management Plan on grounds of imperative reasons of over-riding public interest 'given that coastal flooding and erosion poses a risk to 51,000 residents and commercial properties, two major ports, industrial assets and key infrastructure' (DEFRA, 2011); and

- creation of 300–400 ha of intertidal mudflats and saltmarshes via managed realignment of coastal defences at Medmerry in the eastern Solent by the Environment Agency to compensate for the potential damage to designated intertidal mudflats and saltmarshes across the region from coastal squeeze as required by the Conservation of Habitats and Species Regulations 2010, and to improve the standard of local coastal flood protection to people and property (Environment Agency, Chichester District Council and Arun District Council, 2009).

The enactment of recent legislation and, in particular, the development of policies set out in Shoreline Management Plans for the Solent involved considerable consultation between central Government bodies, local authorities and the general public as individuals, groups and larger organizations (see, for example, New Forest District Council, 2010). The majority of the Coastal Defence Strategies across the Solent remain a 'work in progress' or in draft stage subject to approval, and the 'no let loss' targets for intertidal mudflats and saltmarshes set out in local Coastal Habitat Actions Plans remain unachieved. It is clear that the conflicting legislative and policy requirements discussed in this section to protect people and property from coastal flooding and erosion, and to simultaneously conserve and sustainably use intertidal mudflats and saltmarshes present a challenge to all those involved, requiring accommodations of perspectives regarding where compromises can or cannot be made. The situation is further complicated when the requirements of other legislation, such as the Marine and Coastal Access Act 2010, are also taken into account.

4.3.3 Practice

Practice relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent exhibits a general shift from reclamation to reparation during the time period considered by this research.

Historically, the reclamation of intertidal mudflats and saltmarshes for anthropogenic purposes is known to have occurred in the harbours and estuaries of the Solent since at least the medieval times (Tubbs, 1999). However, this research only considered reclamation that occurred since 1800 because it is not well-documented prior to this date. Reclamation was undertaken for agricultural and industrial development, with the latter being particularly prevalent in Southampton Water (Figure 4.6). In 1832, part of the area known as Salt Marsh on the Itchen-Test peninsula was sold by Southampton Corporation (now City Council) for the construction of Terminus Rail Station. The remaining area of Salt Marsh was subsequently reclaimed following the enactment of the Marsh Improve-

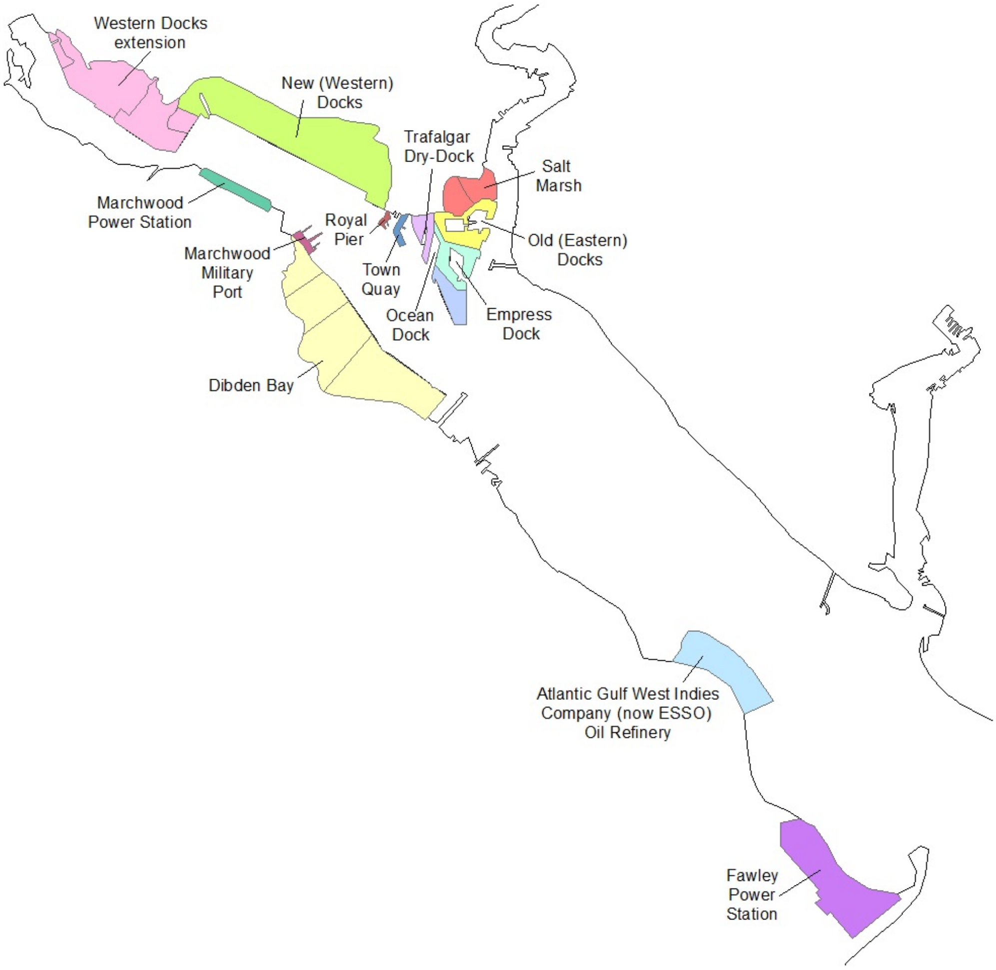


Figure 4.6 Reclamation in Southampton Water post-1800 (indicative boundaries based on Coughlan, 1979)

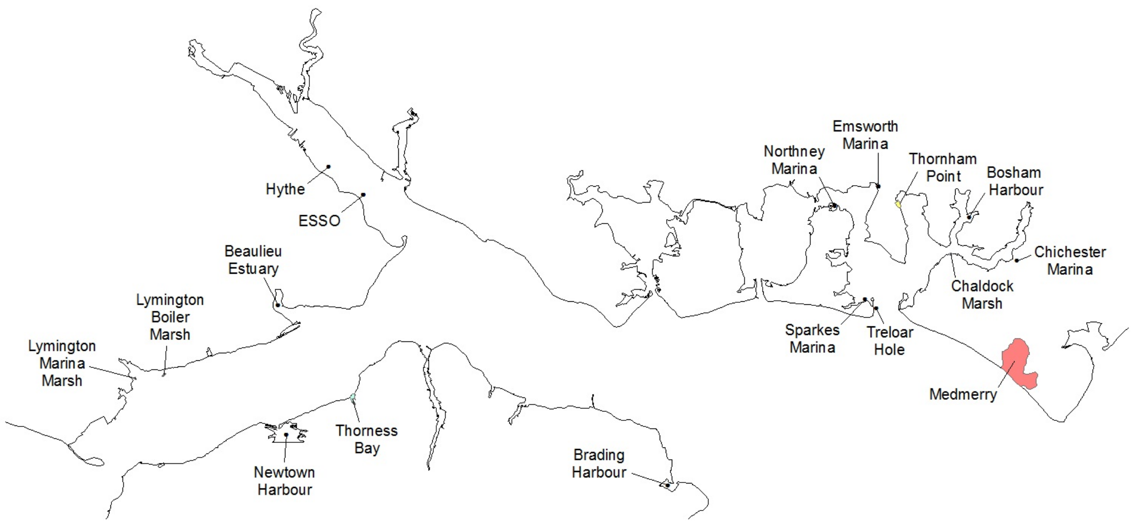


Figure 4.7 Intertidal mudflat and saltmarsh reparation schemes in the Solent (indicative boundaries based on ABPmer, 2012; Black and Veatch, 2012; Environment Agency, 2009a; Google Maps, 2013a,b,c)

ment Act 1844. In 1836, Southampton Dock Company acquired 216 ha of mostly intertidal mudflats for the construction of the Old Docks. The construction works were completed in 1842 for the for the Outer Docks and in 1851 for the Inner Docks. The Company later excavated Empress Dock in 1890. This was followed by the reclamation of intertidal mudflats and saltmarshes for further construction purposes, including: Ocean Dock by London and South Western Railway Company in 1911; a small oil refinery, which was progressively enlarged, by Atlantic Gulf West Indies Company (now ESSO) in 1920; New (Western) Docks by Southern Railway between 1927 and 1933; Dibden Bay (for potential dock development) between 1940 and 1967; Marchwood Military Port by the UK Government in 1943; Marchwood Power Station in 1952; Fawley Power Station by National Power in 1962; and Western Docks extension by the British Transport Docks Board between 1970 and 1997 (ABP, 2010; Coughlan, 1979). Tubbs (1981) estimates 690 hectares of intertidal mudflats and saltmarshes were reclaimed in Southampton Water for these purposes collectively. As discussed in subsection 4.3.2, the cease in reclamation practice in the mid-1970s coincides with the adoption of international nature conservation agreements and legislation, and the enactment of national legislation and polices to meet their requirements. Nonetheless, the legacy of past reclamation continues to ignite debate regarding proposed dock expansions at Dibden Bay by Associated British Ports (ABP), despite the proposals being previously rejected on environmental grounds following a public inquiry in 2001/02 because they would not be adequate to permit the Secretary of State to meet the requirements of the Habitats Regulations (Hurley, 2003).

Intertidal mudflat and saltmarsh reparation schemes in the Solent (Figure 4.7) have until recently comprised relatively small-scale, *ad hoc* projects aimed at addressing a particular issue of concern in isolation from the wider problem of intertidal mudflat and saltmarsh erosion occurring across the region (chapter 2). The first known IMSR schemes in the Solent involved *Spartina* planting to stabilize intertidal mudflats in the Beaulieu estuary by Beaulieu Estate in 1898, in Brading Harbour in 1928, in Newtown Harbour in 1933 (Hubbard and Stebbings, 1967), and following the contamination of saltmarsh by oil pollution, in Southampton Water by ESSO in 1983 (Brooke *et al.*, 2000). This was proceeded by a small-scale trial using coir fibre rolls to defend the leading edge of an eroding saltmarsh from wave attack in Lymington Harbour by New Forest District Council in 1994 (Environment Agency, 2007a), and a managed realignment project by Chichester Harbour Conservancy in 1997 at Thornham Point following sea breaching of coastal defences (ABPmer, 2010); much of the subsequent IMSR practice has since occurred within Chichester Harbour. The Conservancy planted *Spartina* cordgrass on a former car park at Bosham

Harbour in 1998 (Brooke *et al.*, 2000), and undertook a regulated tidal exchange project at Chalkdock Marsh in 2000 (ABPmer, 2010). The beneficial use of maintenance dredged materials from Chichester marina was trialled at Treloar Hole in 2004 rather than disposing of the materials offshore, and subsequently, maintenance dredged materials from Northney, Emsworth and Sparkes marinas have also been disposed of at the same site (Davis, 2005a; Dredging News Online, 2007, 2008, 2010). Elsewhere in the Solent, IMSR schemes include: a beneficial use trial on the foreshore at Hythe by Associated British Ports Marine Environmental Research (ABPmer) in 2001 as part of the Dibden Bay dock expansion proposals (Hurley, 2003); a managed realignment project at Thorness Bay by the Island 2000 Trust in 2004, regarding which little is known (ABPmer, 2010); two beneficial use schemes in Lymington Harbour in 2012 by Lymington Harbour Commissioners (Black and Veatch, 2012) and by Wightlink Ferries (ABPmer, 2012) to mitigate for the adverse impacts to Natura 2000 sites under the Habitats and Species Regulations 2010 from breakwater construction and the operational impacts of new larger ferries respectively; and most recently, a large-scale managed realignment project by the Environment Agency at Medmerry to compensate for the adverse impacts of 'hold-the-line' coastal flood and erosion risk management policies in the North Solent Shoreline Management Plan (see subsection 4.3.2). However, despite increasing efforts taken across the region to conserve and sustainably use intertidal mudflats and saltmarshes, practice so far has not been adequate to address the scale of their loss (see section 1.3). The conflict between the need to meet legislative and policy obligations to conserve and sustainably use intertidal mudflats and saltmarshes, and to simultaneously demonstrate that proposed IMSR schemes will have 'no adverse effect' to the integrity of designated sites continues to hinder or prohibit progress, particularly where trade-offs are required between intertidal mudflats and saltmarshes or other habitat types designated for their conservation interest, such as coastal grazing marsh (Gardiner *et al.*, 2008).

4.4 Conclusions

The research presented in this chapter addressed a knowledge gap by constructing a timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from the perspective of those involved, in order to establish *what* is actually happening, *why*, *how*, and by *who*.

The evidence demonstrates an abundance of research and consultation for legislation and policy development purposes, with a relative lack of practice to actively conserve and sustainably use intertidal mudflats and saltmarshes across the Solent. The majority of the events identified in this study were not aimed directly towards the conservation and sustainable use of intertidal mudflats and saltmarshes, but rather served some other purpose which indirectly influenced this aim, e.g. coastal flooding and erosion risk management, and dock development. Research, legislation and policy, and practice are inherently linked in a complex web, with changes in one domain being reflected in another. Yet despite the significant investment in research and consultation processes by a diverse range of people as individuals, small groups and larger organizations over numerous years, no clear end point appears to have been reached in terms of realizing intertidal mudflat and saltmarsh conservation and sustainable use in the Solent.

Towards this end, the findings from this research enable further in-depth studies to be undertaken in order to recommend and evaluate changes to improve the decision-making process through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken. Furthermore, the concepts and methods applied in this study are transferable (subject to the availability of data and the co-operation of local stakeholders) to other coastal regions where the conservation and sustainable use of intertidal mudflats and saltmarshes is problematic; and also to other complex, problematic decision-making situations in the UK and elsewhere, such as those concerning spatial planning, green infrastructure, transportation and energy use, in which there is a potential need to better understand specifically what is happening, why, how and by who from the perspective of those involved.

Chapter 5

Decision-making for conservation and sustainable use through the lens of multi-methodology systems intervention

5.1 Introduction

Despite a long-standing recognition of the importance and value of intertidal mudflats and saltmarshes, and the inherent consequences of their ongoing loss to the well-being of humans and other species, surprisingly little is known about the process (or system) by which stakeholders make decisions and take actions towards improving their conservation and sustainable use. Towards alleviating this knowledge gap, in the absence of previous relevant research, chapter 4 constructed a timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from 1800 to 2016 to establish what is actually happening, why, how and by who. The evidence demonstrates that in most cases the events were not directly concerned with the conservation and sustainable use of intertidal mudflats and saltmarshes, but rather served some other purpose which indirectly influenced this aim, such as coastal flooding and erosion risk management, and dock development. Research, legislation and policy, and practice to actively conserve and sustainably use intertidal mudflats and saltmarshes are interconnected in a complex web, with changes in one domain influencing those in another. Yet despite a significant investment by many people over numerous years in research and consultation for legislation and policy development purposes, there remains a relative lack of practice, and no clear end point appears to have been reached in terms of realizing intertidal mudflat and saltmarsh conservation and sustainable use.

Building on the work in chapter 4, the purpose of the research presented in this chapter was to undertake further in-depth studies to understand decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes, in order to recommend changes to improve the decision-making process through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken. The study used multi-methodology systems intervention as a lens through which to view and make sense of what the existing decision-making process is, and how to intervene to change (improve) it. This chapter describes the research method, then presents and discusses the results and implications of this study.

5.2 Data and methods

Multi-methodology systems intervention involves combining systems approaches, in whole or in part, for the purpose of resolving a complex problem situation. Systems approaches seek to resolve a problem situation by understanding the relationship between its constituent parts, rather than by decomposing it into consecutively smaller parts and studying each part separately. This enables properties to be observed that cannot be found from the properties of the component parts individually (Reynolds and Holwell, 2010).

Researchers and practitioners remain engaged in discourse regarding the best ways to choose and apply systems methodologies, and it is not appropriate to re-open the debate here, other than to reiterate that Midgley (1997), Mingers and Brocklesby (1997) and Jackson (2000) assert that different methodologies each focus on different aspects of the problem situation, and thus, multi-methodology is necessary to address the full richness of a complex problem situation. Furthermore, that intervention typically proceeds through a number of phases, which pose different challenges for the researcher or practitioner. Methodologies tend to be more useful in relation to some phases than others, so combining them may yield a better result. In this context, Midgley (1990) insists that the complete research design need not be determined in advance but may evolve as understandings of the problem situation develop.

With the above in mind, the Open University's (2006a) framework for environmental decision-making was chosen as the starting point and cornerstone for intervention. As discussed in chapter 3, the framework is not known to have featured previously in multi-methodology systems intervention. The rationale for its use in this context was based on the recognition of its ability to enable a variety of systems approaches to be used in combination for the purposes of developing understandings and practices to improve decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes:

- It provides a structure to guide the researcher through four phases of intervention, which together comprise a learning cycle: (re-)explore the situation, formulate problems and opportunities, identify feasible and desirable changes, and take actions.

- The cyclic, iterative nature of the framework enables intervention to be a process of learning that allows for continuous improvement, rather than a constrained activity that stops once a decision has been made.

- It promotes the use of systemic and systematic thinking, as well as the use of a combination of hard, soft and critical systems approaches, rather than one or another.

- It is non-prescriptive, allowing the researcher to choose and apply methodologies (or parts thereof) at each phase of intervention with the benefit of hindsight from the preceding phase(s).

Two iterations of the framework were used in this study. The purpose of the first iteration was not only to explore and understand what *is* done in terms of decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes, but also to consider what *could* (or perhaps *should*) be done, i.e. alternative modes of practice in decision-making, and the benefits/insights gained from doing so. The purpose of the second iteration was to further consider what might constitute an improved decision-making process, and hence, what changes in practice might be both feasible and desirable to improve decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes.

The framework was operated in this study through the use of a combination of techniques derived primarily from three systems approaches: soft systems methodology, system dynamics and critical systems heuristics. Numerous sources describe these approaches in detail (e.g. Checkland and Poulter, 2010; Morecroft, 2010; Ulrich and Reynolds, 2010), and thus, they are not described again here. However, the techniques used in the study, and the purposes for their use, are explained where appropriate in section 5.3. Consistent with Midgley (1990), the methodologies and techniques were not pre-determined, but were allowed to evolve as understandings of the situation (or system) of interest developed throughout the study. It is acknowledged that there is a limit to the researcher's knowledge and experience in the use of systems approaches, which influenced the choices made. Furthermore, that alternative choices could have been made, perhaps for example by using strategic options development and analysis or strategic assumption surfacing and testing instead of soft systems methodology, or the viable systems model instead of system dynamics; and that different insights or avenues for investigation may have resulted from doing so. Thus, it is not asserted that the overall research design used in this study is the best means of intervention, only that it is one possible means of intervention. It should also be stressed that the study makes no claim towards being objective. The views expressed, and encapsulated in models for the purpose of facilitating discussion, represent those of the researcher based entirely on an interpretation of the timeline of events described in chapter 4.

5.3 Results and discussion

Sections 5.3.1 to 5.3.4 summarize the first iteration of the framework. Sections 5.3.5 to 5.3.8 summarize the second iteration of the framework.

5.3.1 Explore the situation

5.3.1.1 Starting out systemically

Systemic awareness — an awareness of the situation as a whole — comes from understanding cycles, counter-intuitive effects and unintended consequences. The process of developing systemic awareness begins with 'standing back' and resisting pressures to rush towards a preconceived solution by exploring (or re-exploring) the wider context of a situation using tools and techniques which encourage divergent thinking (Open University, 2006b), such as rich pictures, which originate from soft systems methodology (Checkland, 1981, 2000; Checkland and Scholes, 1990).

The rich picture shown in Figure 5.1 depicts the decision-making situation as experienced by the researcher from the first engagement with key documents. The aim was to capture the perspective of the researcher and to communicate it to others as well as to evoke insight into the situation. From the rich picture, it is conceivable that the decision-making process fails to start out systemically. It is characterized by 'passing the buck', with each organization passing on the responsibility to make a decision. This leads to the hypothesis that the emphasis on research and consultation, which clearly dominates here, is not conducive to delivering systemic outcomes. Consideration was also given to whether the dominant viewpoint is depicted fairly, which exemplifies the need to explore a situation from multiple perspectives.

5.3.1.2 Exploring through modelling

Having identified themes for consideration from 'brainstorming' techniques such as rich pictures, it is useful to identify boundaries within a system of interest, and to classify

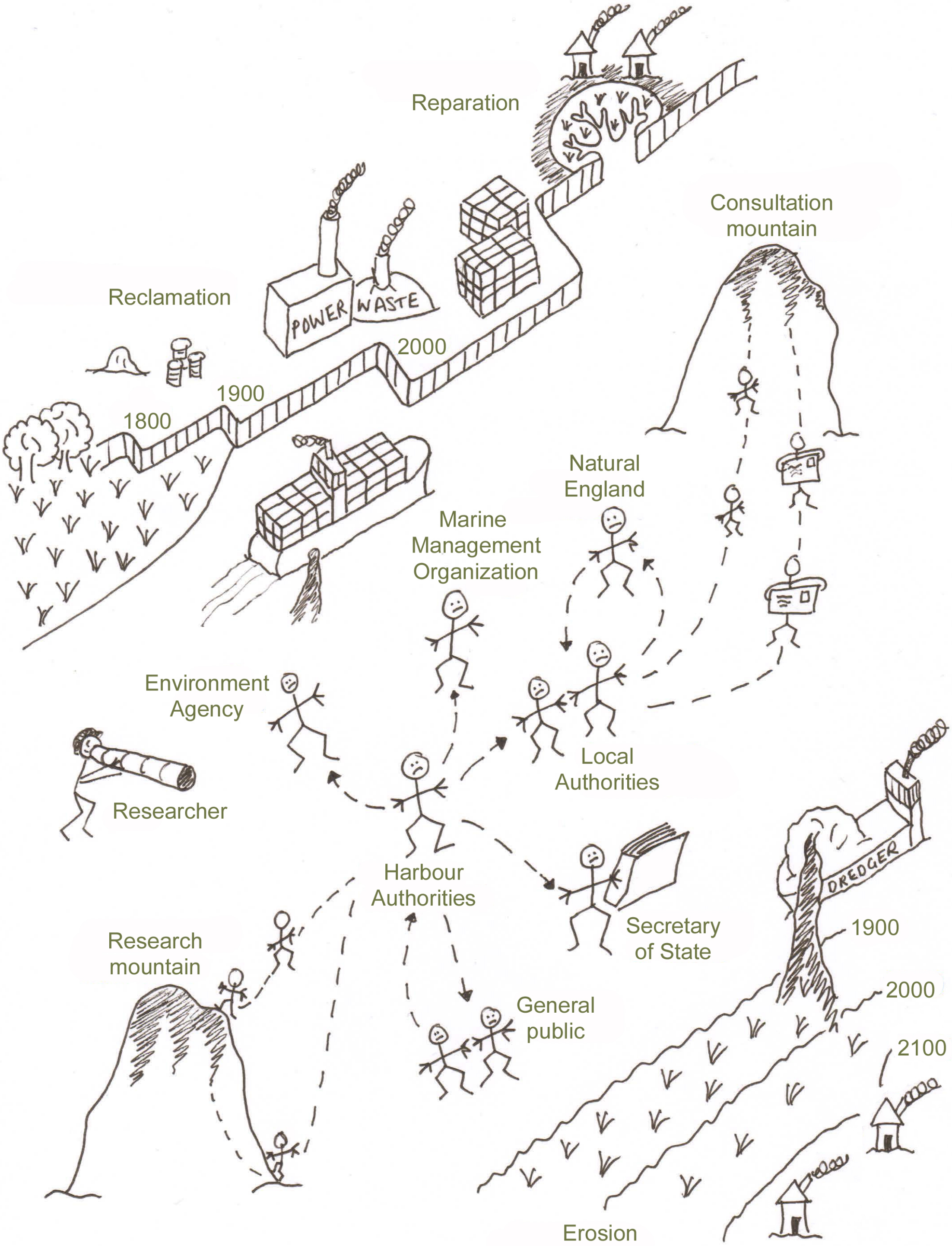
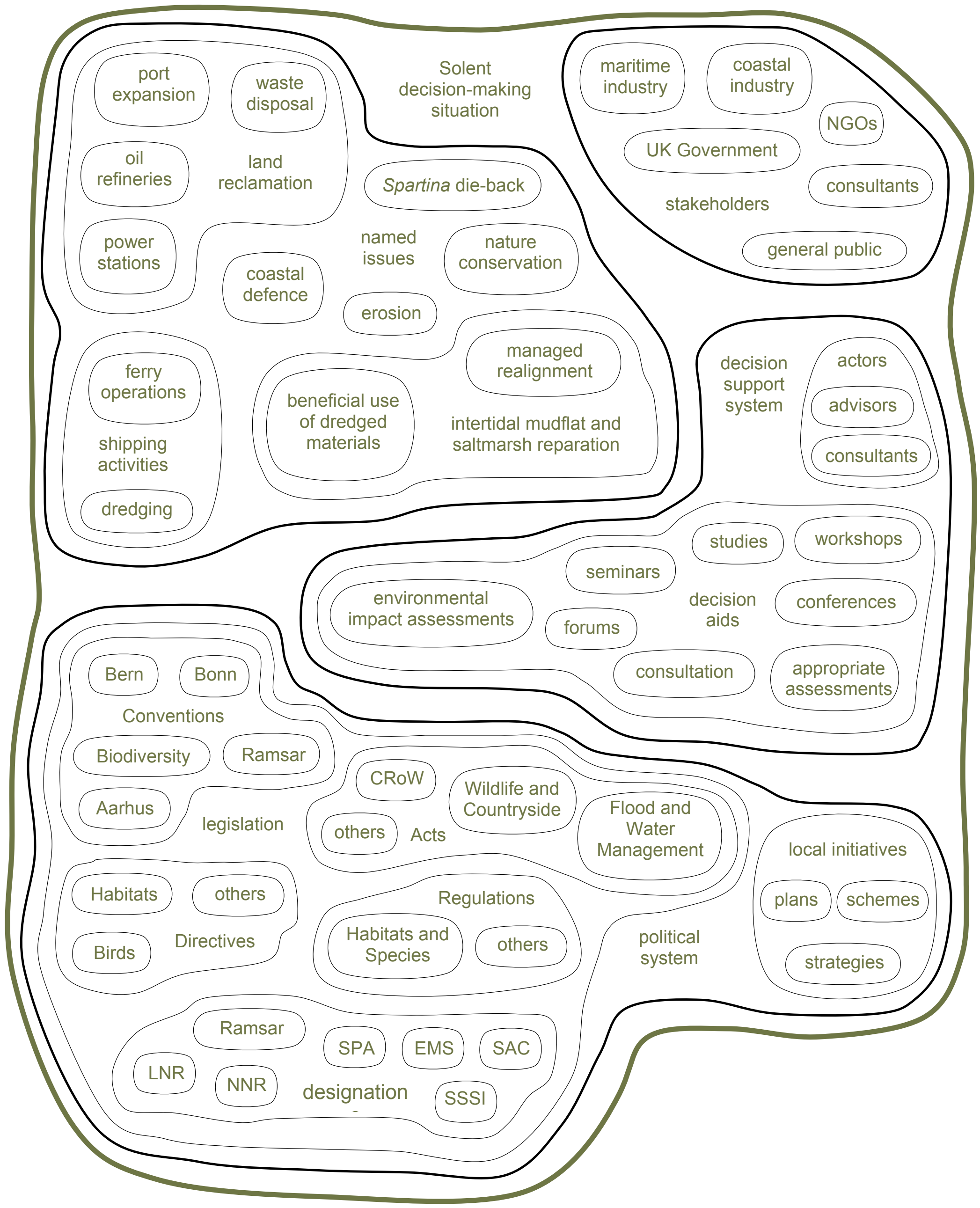


Figure 5.1 The decision-making situation of interest for the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from the perspective of the researcher

components of the system within a nested set of boundaries. Systems maps, which were developed by the Open University for teaching purposes, are an important modelling technique for this purpose (Open University, 2006b).



SAC = Special Area of Conservation
SPA = Special Protection Area
CRoW = Countryside and Rights of Way
SSSI = Site of Special Scientific Interest
EMS = European Marine Site
LNR = Local Nature Reserve
NNR = National Nature Reserve

Figure 5.2 The decision-making system of interest for the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from the perspective of the researcher. The relative position of the sub-systems and the elements within them is arbitrary

The systems map shown in Figure 5.2 illustrates the structure of the decision-making system of interest, showing clearly the proposed boundary and the sub-systems that the researcher regards as important. The multiple cause diagram (Open University, 2006b) shown in Figure 5.3 was derived from the systems map. It looks more specifically at the interrelationships between the main factors that affect decision-making, and thus, it starts to move away from a 'snapshot' analysis to a more dynamic assessment of the situation.

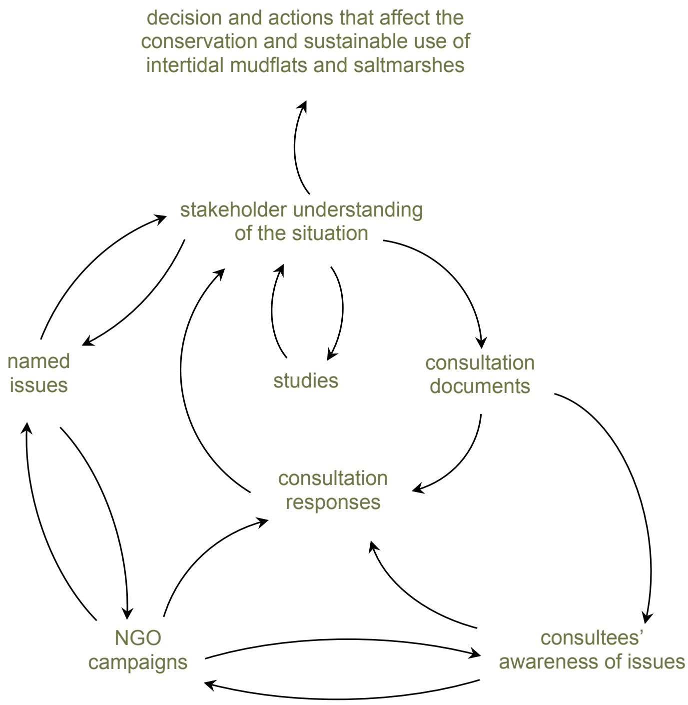


Figure 5.3 Interrelationships between factors that affect decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent

The main insight gained from Figure 5.3 is to recognize that 'stakeholder understanding of the situation' is an output of the system as well as an input. The key point to note, however, is that the range of diagramming techniques illustrated here can be used together in a comprehensive exploration of a situation, which may lead to new insights and/or avenues of investigation that may initiate modifications of previous diagrams or a new set of exploratory diagrams altogether (Open University, 2006b); but, the use of such tools and techniques in the Solent decision-making situation appears to be very limited.

5.3.1.3 Systems thinking for exploring

Systems thinker, West Churchman (1971), once claimed that systems thinking begins when you can put yourself in the mind of another, which conveys that a key aspect of developing systemic awareness is to allow for multiple partial perspectives to inform a decision-making process. One approach to doing this is stakeholder analysis (Grimble and Wellard, 1997). 'Stakeholders' are a group of people that have a stake — an interest, common or different — in the situation or issue under consideration from *their* perspective (Open University, 2006b).

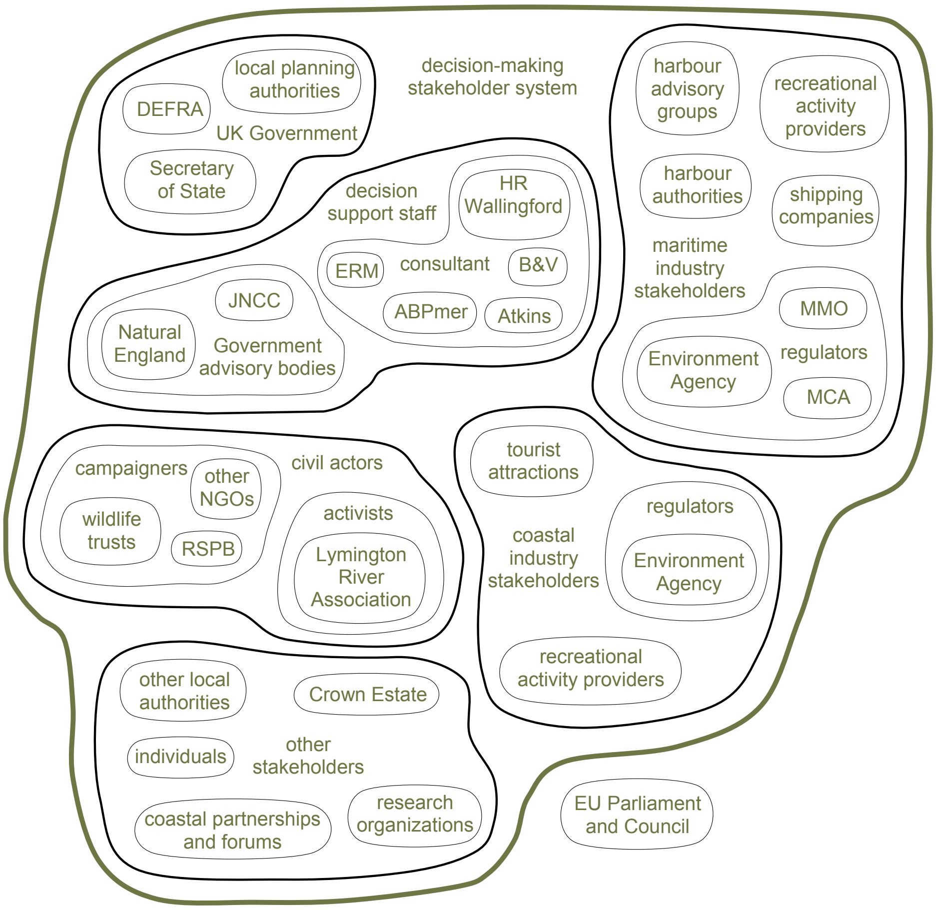


Figure 5.4 Stakeholder analysis of the Solent decision-making situation. The relative position of the sub-systems and the elements within them is arbitrary

The systems map shown in Figure 5.4 was used to construct a stakeholder analysis of the decision-making system of interest from key documents, including summaries of consultation responses. Based on Figure 5.4, the key stakeholders are the general public, including individuals, small groups and larger organizations, since these are the persons directly affected by the outcomes of the decision-making process. The UK Government is also an important stakeholder since it is both the sponsor (owner) of the decision-making situation and also generally the main actor, i.e. it conducts many of the activities in the decision-making situation.

The following describes the researcher's understanding of the perspectives of the situation held by some of the stakeholders identified in Figure 5.4.

UK Government

It is common within Government for there to be mixed perspectives of a situation, e.g. where cuts should be made to alleviate deficits in expenditure, but in this case, there appears to be wide-spread support for intertidal mudflat and saltmarsh reparation. The Environment Agency (2007a, p.1) state:

> ‘Saltmarsh maintenance, restoration or enhancement is increasingly being considered as a means of managing flood risk. It also has the advantage of enhancing the conservation importance of a ‘natural’ as well as a frequently designated, priority and Biodiversity Action Plan habitat’.

Natural England

Natural England advise the UK Government on environmental issues. Their perspective of the situation is embodied in the following quote from Natural England (2010, p.5–6):

> ‘In view of sea level rise predictions (around a metre over the next 100 years), Natural England does not believe that the marshes of the south and east of England have a long term sustainable future in many of their current locations. Instead Natural England’s long term priority is to work with others to achieve coastal adaptation to sea level rise where the mosaic of coastal habitats can roll back, where possible, and form on currently higher ground [...] Within this long term view of the inevitable consequences of sea level rise it is still the case that human-induced net losses and damage to designated coastal habitat should not occur and this remains Natural England’s responsibility [...] Despite our views of the long term priorities for coastal management, Natural England also accepts that there can be benefits for wildlife, and of course particularly for coast protection, in schemes to better manage or prolong the life of saltmarshes in the short to medium term (0-50 years)’.

Hampshire and Isle of Wight Wildlife Trust

Hampshire and Isle of Wight Wildlife Trust are a nature conservation charity. They demonstrate mixed perspectives. They have campaigned for and against intertidal mudflat and saltmarsh reparation schemes in the Solent. For example, they proposed a managed realignment scheme in the Lower Test (Chatters, 2003), but object to the managed realignment of Farlington marshes (New Forest District Council, 2010). Regarding a local ‘beneficial use’ project, they state:

> ‘Despite the misgivings that we still have regarding the proposals, we do recognise the value of carrying out a large scale trial of this nature and accept that the degree of certainty that we would expect in a terrestrial environment is unrealistic on a rapidly changing marine habitat. We will therefore not oppose the scheme being carried out’ (Natural England, 2010, p.7).

General public

Local stakeholders appear to be generally against the concept of managed realignment, and sceptical, but less opposed to 'beneficial use' schemes (c.f. Natural England, 2010; New Forest District Council, 2010). Consider, for example, the following comment which is representative of a number of consultation responses made by individuals:

> 'I am a nature lover, conservationist and greener than most BUT we should stop pussyfooting around with all this managed retreat and increase the height of the sea banks [...] Nature is very adaptable and we might lose some species but we would gain or retain others. Homes and people are more important' (New Forest District Council, 2010, p.347).

Bearing all of the above in mind, it is certainly clear that a wide range of stakeholders are included in the decision-making process, and that there are a diverse range of stakes. But, as noted by the Open University (2006c), to fully understand 'who decides?', in addition to knowing who is involved, it is also important to consider how and when people are involved in the decision-making process, which is discussed in the following sections.

5.3.2 Formulate problems, opportunities and systems of interest

5.3.2.1 Consultation or participation?

Consultation clearly features very strongly in the decision-making process, but not at the starting out stage. For example, there seemed to be little consultation in formulating the options to be included in the consultation documents. The point here is that the question that had to be answered — i.e. the naming of the problem (or opportunity) — preceded the consultation process. But, the suggestion here that people were not involved as much as they could be is not implying that there should have been more consultation, but rather that people could have been involved differently. As suggested by Ison (2006, p.225) with regards to the UK aviation white paper consultation process, perhaps starting out with 'some form of stakeholder analysis which led to the design of a process to articulate different perspectives and to frame different sorts of questions for the consultation may have been an improvement'. Consider, for example, the following techniques which can be used to accommodate multiple perspectives in formulating problems, opportunities and systems of interest.

5.3.2.2 BATWOVE and root definition

Root definition is a part of the terminology of soft systems methodology (Checkland, 1981, 2000; Checkland and Scholes, 1990). It is a statement that concisely describes a system of interest, and it should include mention of all the key elements of the system. It takes the form: a system to do P (what) by Q (how) in order to achieve R (why). Various mnemonics have been suggested to help the process of formulating a root definition, one such is BATWOVE (Midgley and Reynolds, 2001), as shown in Table 5.1. It was used in this instance because it makes explicit the Beneficiaries and Victims of the system, which can be conflated under 'Customers' in the original mnemonic CATWOE (Customers, Actors, Transformation, Worldview, Owners and Environmental constraints) proposed by Checkland (1981).

Table 5.1 BATWOVE applied to the Solent decision-making situation

Beneficiaries	UK Government, humans and other species whose well-being depends on intertidal mudflats and saltmarshes, e.g. walkers, bird-watchers, fisheries
Actors	UK Government, marine and coastal industries, NGOs, individuals
Transformation	Preferred option to mitigate human-induced damage to designated intertidal mudflats and saltmarshes unapproved $\rightarrow$ preferred option approved (or rejected)
Worldview	Approval for the preferred option which meets the obligations of the Habitats and Species Regulations can be achieved by consultation with statutory consultees and the general public
Owners	UK Government
Victims	Coastal landowners/residents, and other types of marine and coastal habitats and species, e.g. coastal grazing marsh, particularly where trade-offs are required
Environment	Resource constraints (e.g. time, money), limited opportunities for consultees to ask questions, failure to learn from past events and perceptions that things will fail

The following root definition of the Solent decision-making system was developed from Table 5.1:

> 'A system owned and operated by the UK Government to seek approval for the preferred option to mitigate human-induced damage to designated intertidal mudflats and saltmarshes as decided by the person(s) responsible for the damage based on scientific studies, by means of consultation with statutory consultees and the general public, within a set time limit and with limited opportunities for consultees to ask questions before submitting a response, in order to meet the obligations of the Habitats and Species Regulations'.

Note that this root definition represents the perspective of the researcher, and thus, it is relevant only to the researcher in the context of this study. Other people will have different worldviews, and hence, have a different system of interest. Nonetheless, it serves to demonstrate that if constructed by multiple stakeholders, a root definition can help to alleviate clashes of perspective and purpose which can lead to conflict when identifying feasible and desirable changes, or inaction, because there is no agreement on the nature of the problem (*what*) nor agreement about *how* to proceed or what might constitute success (*why*) (Open University, 2006b).

5.3.3 Identify feasible and desirable changes

5.3.3.1 Consultation approach

As suggested in subsubsection 5.3.2.1, public involvement in the decision-making process is largely by consultation rather than by other forms of participation, and based on the available evidence, it could also be claimed that the consultation process perhaps serves more as a means to seek approval for a preferred option rather than to determine what might constitute feasible and desirable changes to the situation from a public perspective. There are also many outstanding questions regarding how and why certain options have been deemed feasible or desirable. For example, the consultation regarding mitigating the operational impacts of Wightlink's ferries to designated areas considered only a single option — Wightlink's preferred option — and it is unclear how or why Wightlink decided upon their preferred option as opposed to taking any other form of mitigating action (c.f. ERM, 2010a; Lymington Society, 2012; Solent Protection Society, 2011). This approach has in many cases led to multiple diverse perspectives of the situation, and to considerable objections to the preferred option. Some form of transparent, robust modelling may be appropriate here in order to clarify what constitutes feasible and desirable changes. Consider, for example, the following models that take guidance from earth systems which, like previous models, can be used together to identify feasible and desirable changes.

5.3.3.2 Other approaches

The Environment Agency (2007a) state that the selection of the most appropriate actions to conserve and sustainably use intertidal mudflats and saltmarshes should be informed by a robust, but simple analytical process which enables the environmental, social and economic impacts of intervention to be fully understood. In this context, the causal loop diagram (or sign graph) shown in Figure 5.5 was constructed to determine the dynamic relationship between key factors associated with intertidal mudflat and saltmarsh reparation, and to consider the likely effects of changes, particularly interventions, in the system (Open University, 2006e). It shows that there are several feedback loops which are linked together by saltmarsh extent.

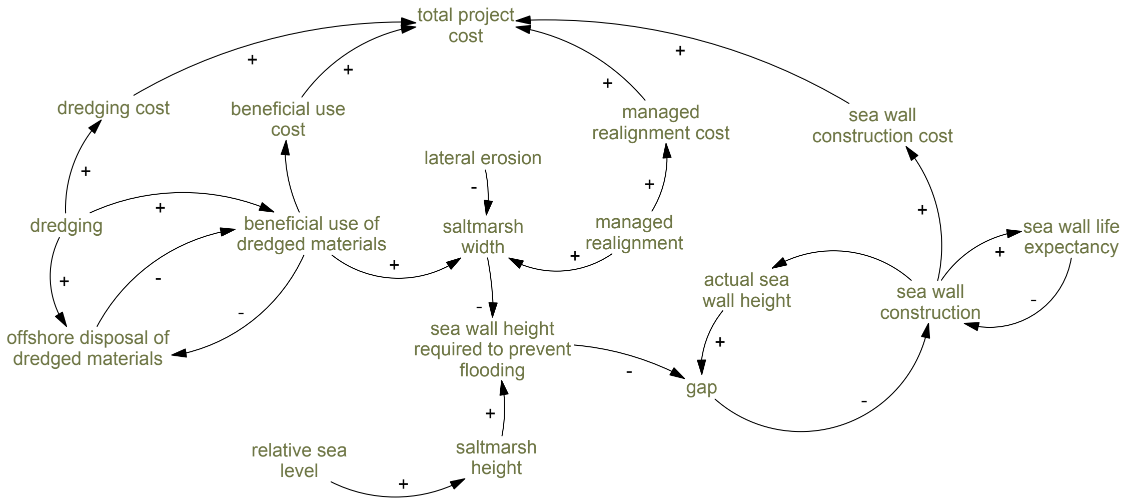


Figure 5.5 Dynamic relationship of key factors associated with intertidal mudflat and saltmarsh reparation

The system dynamics diagram (Forrester, 1961) shown in Figure 5.6 was developed to further clarify the relationships between these variables. It particularly highlights that a key anthropogenic factor which affects the conservation and sustainable us of intertidal mudflats and saltmarshes is the method of disposal of dredged materials: beneficial use of dredged materials increases saltmarsh extent, whereas offshore disposal does not. With the exception of the recent beneficial use schemes (as discussed in section 1.3), dredged materials from the Solent region are disposed of at offshore sites. So, these are potential areas in which changes could be made to improve the conservation and sustainable use of intertidal mudflats and saltmarshes. Furthermore, the outcomes of simulation models such as these can be used to inform other decision-making approaches, such as multi-criteria analysis, which establish preferences between options by reference to an explicit set of objectives identified by decision-makers (Open University, 2006e).

It must be borne in mind, however, that the outcomes of all models inherently contain some degree of uncertainty as a consequence of the need to make assumptions and value judgements as a part of the modelling process, e.g. when input data are either unavailable or unclear. Appreciating that these uncertainties exist, and thus, that model results should never be regarded as 'absolute' but as an estimate of reality (Open University, 2007a) is crucial to understanding the risks associated with the situation and to more effective decision-making which accounts for the risks. But, because of the ways in which different

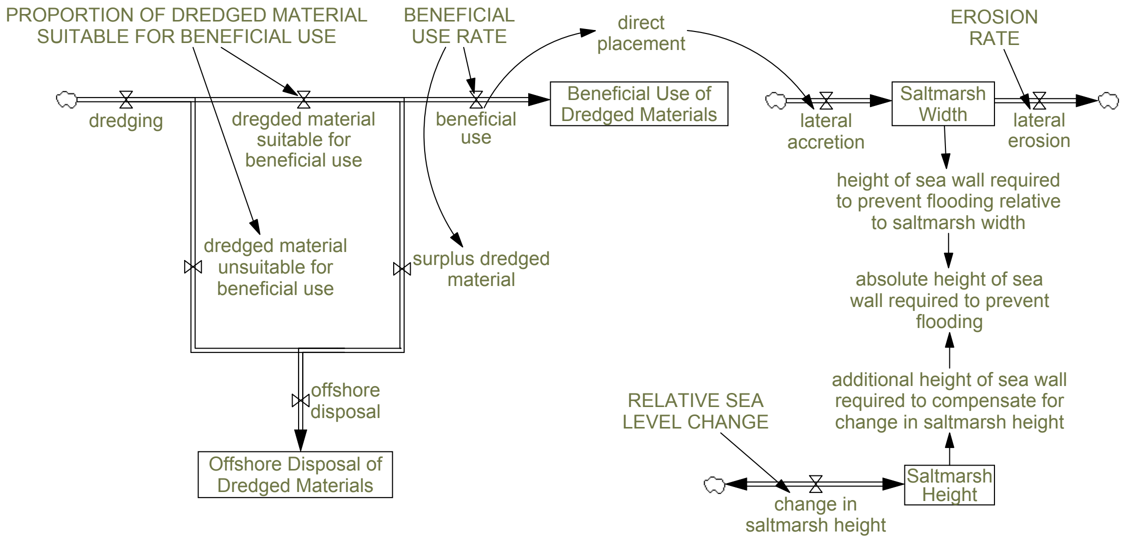


Figure 5.6 A possible system dynamics model of the relationship between factors influencing saltmarsh extent

groups of people involved in decision-making construct risks, assess hazards and make sense of uncertainties, it may still not be possible to choose a singular form of feasible and desirable change. As suggested by the Open University (2006c), what is required is 'social learning'. The key point here is that social learning is concerned with bringing about change as a result of multi-stakeholder interactions. As Woodhill (2002) found, participation alone is not necessarily enough to lead to the changes necessary to address environmental issues. It may be indicative of various learning processes that contribute to identifying feasible and desirable changes but interactions among interdependent stakeholders that go further and bring about institutional as well as local level change are also needed in many contexts (Open University, 2006c).

5.3.4 Take actions

As evidenced in this chapter, considerable effort has been invested in the Solent decision-making situation by many stakeholders. But, the question of whether actions have actually been taken to improve the situation is dependent upon what might be considered to constitute 'action' — which is a matter of opinion.

Research has catalogued changes in the extent of intertidal mudflats and saltmarshes and the species, particularly the birds, that they support (see, for example, Cope *et al.*, 2008; King, 2010; Williams *et al.*, 2010). But, it has so far failed to unequivocally identify the cause of recent erosion (chapter 2). Legislation and policies to protect and enhance intertidal mudflats and saltmarshes have been implemented in responses to the reported losses. They have the potential to really make a difference to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent. But, 'no bulldozers have moved in yet'. Physical actions across the Solent to mitigate for intertidal mudflat and saltmarsh losses have been very limited. All of the recent intertidal mudflat and saltmarsh reparation schemes have been an obligatory requirement under the UK Habitats and Species Regulations to compensate for the adverse impacts to designated areas from human developments rather than for their own sake (chapter 4).

As previously suggested in subsubsection 5.3.1.3, there has been a diverse range of reactions to these actions by local stakeholders. Nonetheless, it is probably not too presumptuous to suggest that most would agree that if we continue to take the current, reactive approach to the conservation and sustainable use of intertidal mudflats and saltmarshes, then we accept the default option — that the intertidal mudflats and saltmarshes will be lost entirely in some areas of the Solent within the next few decades. Concerted actions to implement a long-term, proactive decision-making approach are required by local stakeholders to secure the viability of intertidal mudflats and saltmarshes for the benefit of present and future generations. Towards this end, the following sections further consider what might constitute an improved decision-making process.

5.3.5 Re-explore the situation

A rich picture (Figure 5.7) is again used here as a means of capturing, and communicating to others, the researcher's perspective of what might constitute an improved decision-making situation based on the findings from this investigation. In particular, it highlights a change in the researcher's role and perspective — the researcher is now much more a part of the situation — and themes of interactions amongst stakeholders, which are further developed in the systems map shown in Figure 5.8 and in subsection 5.3.6.

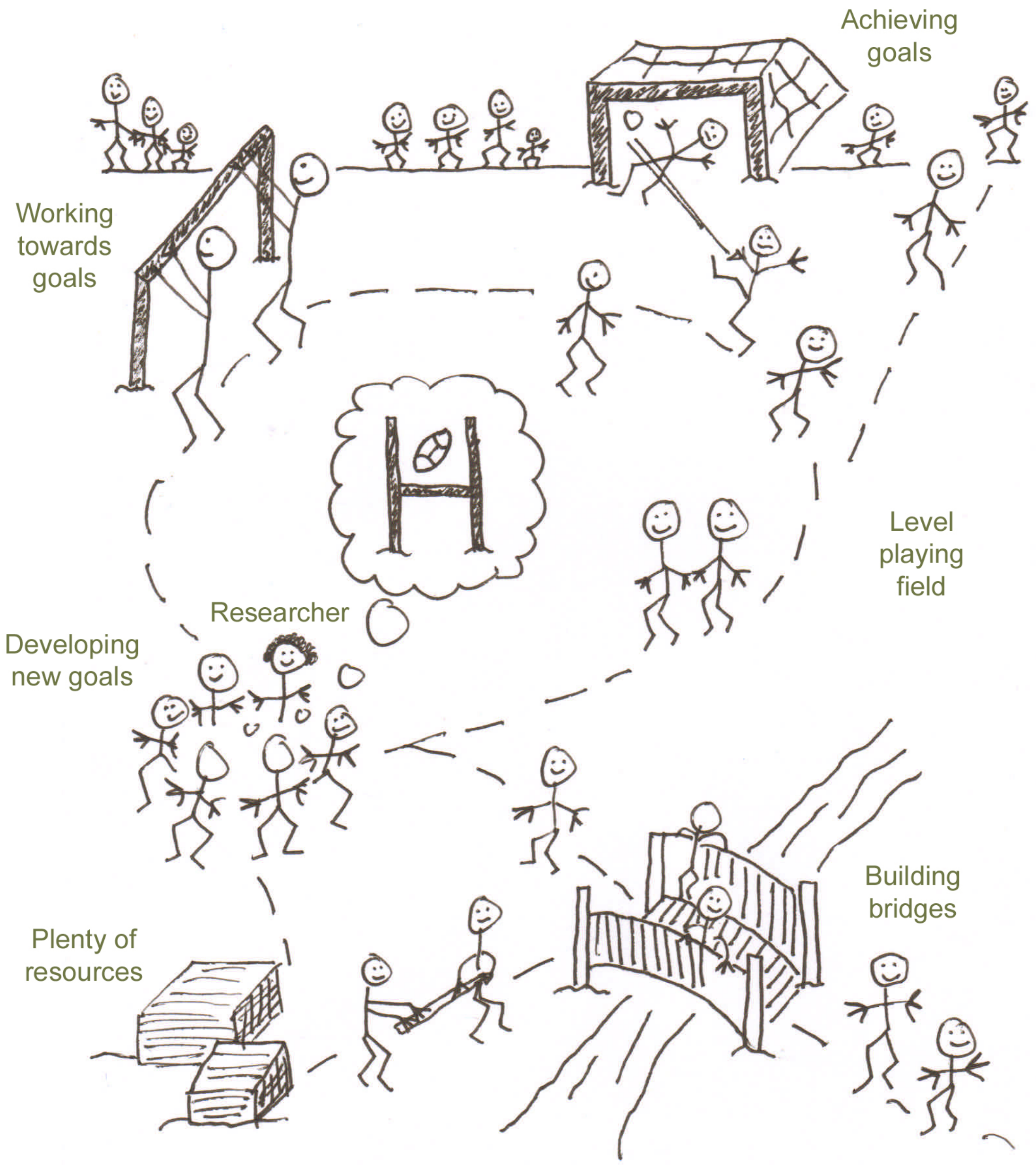


Figure 5.7 A metaphor for an improved decision-making situation from the perspective of the researcher

The systems map was constructed with a particular model of systems practice in mind in which intervention and change in problem situation is a result of the dynamic relationship between: (1) the perceived problem situation; (2) theories or frameworks of ideas, e.g. meta-methodologies and methodologies; (3) methods of applying the theories to the problem situation, e.g. interviews and workshops; and (4) the users of the method, e.g. researchers and practitioners.

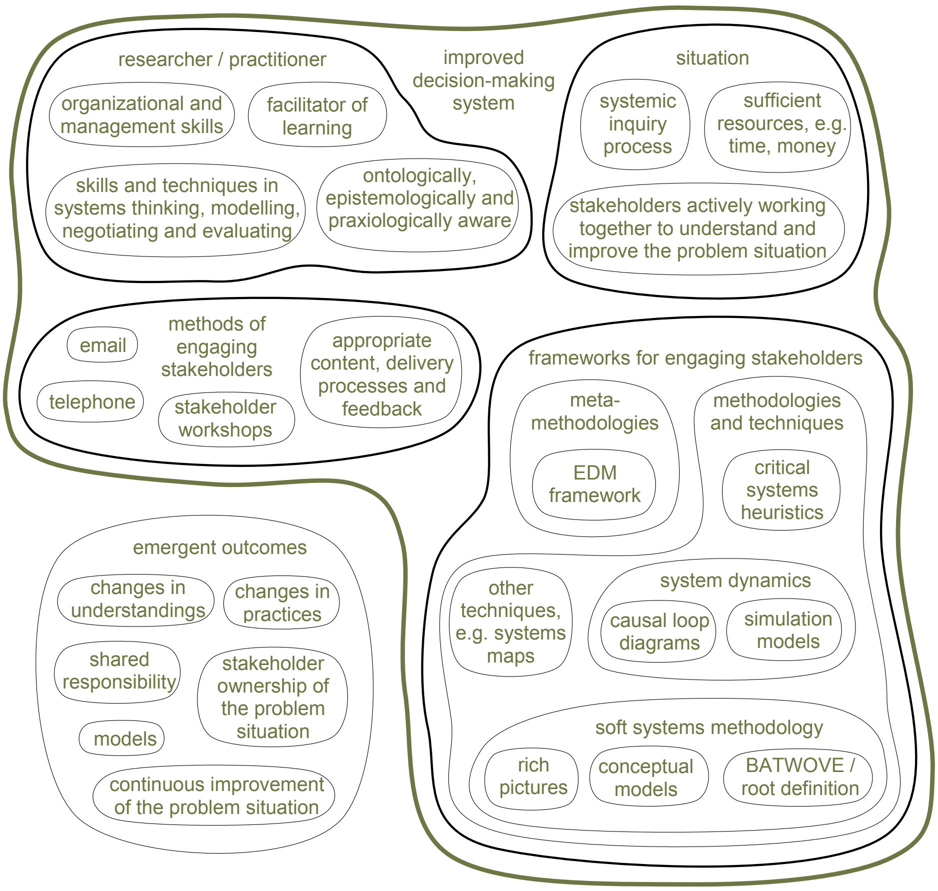


Figure 5.8 An 'improved' decision-making system from the perspective of the researcher

The main insight gained from Figure 5.8 is that changes in understandings and practices, and shared responsibility and ownership of the problem situation, are emergent outcomes of a systemic inquiry process leading to continuous improvements in the conservation and sustainable use of intertidal mudflats and saltmarshes.

5.3.6 Re-formulate problems, opportunities and systems of interest

The elements of BATWOVE shown in Table 5.2 were identified from Figure 5.4, Figure 5.7 and Figure 5.8.

Table 5.2 BATWOVE applied to an 'improved' decision-making situation

Beneficiaries	Local stakeholders, including humans and other species, whose well-being depends on intertidal mudflats and saltmarshes, e.g. walkers, bird-watchers, fisheries
Actors	Local stakeholders including individuals, groups and larger organizations
Transformation	Understandings and practices to conserve and sustainably use intertidal mudflats and saltmarshes unimproved → continuous improvement in understandings and practices to conserve and sustainably use intertidal mudflats and saltmarshes
Worldview	Improvements conducive to meeting the needs of humans and other species can be achieved by using a systemic and systematic social learning approach that accommodates complexity, uncertainty and multiple diverse perspectives in decision-making
Owners	Local stakeholders supported by national Government
Victims	Coastal landowners, and other types of marine and coastal ecosystems, e.g. coastal grazing marsh, particularly where trade-offs are required
Environment	Resource constraints (e.g. money, time), failing to learn from past failure and perceptions that things will fail again

The following root definition, developed from Table 5.2, defines what might constitute an improved decision-making system from the perspective of the researcher.

> 'A social learning system owned and orchestrated by local stakeholders, and supported by national Government, to continuously improve understandings and practices to conserve and sustainably use intertidal mudflats and saltmarshes by using techniques and skills in systems thinking, modelling, negotiating and evaluating as heuristic devices, in order to secure and enhance the delivery of the services provided by these ecosystems upon which humans and other species depend'.

Note the shift in focus in comparison to the root definition given in subsubsection 5.3.2.2, from the mitigation of human-induced damage to designated intertidal mudflats and saltmarshes, to the continuous improvement of understandings and practices to conserve and sustainably use intertidal mudflats and saltmarshes regardless of the cause of damage — whether human-induced or naturally occurring — or designation status. The term 'practices' is specifically used because there may be a variety of ways to take actions rather than solely via managed realignment or the beneficial use of dredged materials, for example.

These ideas are captured in the conceptual model shown in Figure 5.9. The purpose of the model was to further clarify the researcher's understanding of what might constitute an improved decision-making process, and to communicate it to others. It expresses changes in the conservation and sustainable use of intertidal mudflats and saltmarshes in terms of changes in understandings and practices. The term 'change' is used here to imply a

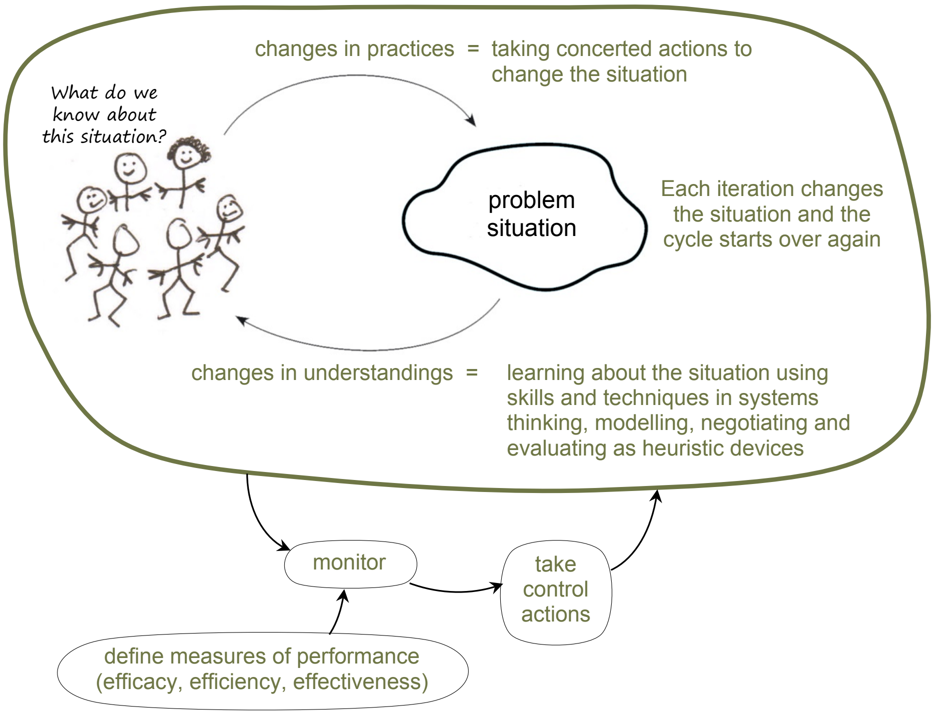


Figure 5.9 A conceptual model of an 'improved' decision-making process through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken (based on concepts and models in Checkland and Poulter, 2010; Open University, 2006b,d)

change for the better (perceived improvement), but as noted by Ison (2006), better is always situation-sensitive. Note that monitoring and evaluating is included as a part of the system. This is important since, as stated by Open University (2006b), 'an open, participatory process has to accommodate the learning of all those involved and be, by its very nature, self-correcting (or evaluating) or else it will fail'.

5.3.7 Identify feasible and desirable changes

Throughout this study, judgements have been made about both what *is* and what *could* be done in terms of deciding the conservation and sustainable use of intertidal mudflats and saltmarshes, which serves to highlight that when decision-making processes are being started today, they could be approached differently. In this context, systemically feasible and desirable changes can be identified by comparing what *is* with what *ought to be* from a theoretical perspective. Critical systems heuristics, developed by Ulrich (1983, 2000) to support boundary critique, is a framework for reflective practice that is appropriate for this purpose. It is based on 12 questions which serve to make explicit the judgements that decision-makers reply on to understand situations and to design systems for improving them (Ulrich and Reynolds, 2010).

Table 5.3 summarizes the application of critical systems heuristics in evaluation mode to the Solent decision-making situation. It brings together and builds on the ideas previously discussed in order to compare what the existing role of consultation and participation is from the perspective of the researcher based on the findings of this investigation, and what it perhaps ought to be in an 'ideal world', that is, in an improved situation. Again, the main purpose here is to clarify the researcher's understanding, to develop possible mutual understandings with others and to prompt further questions around decision-making.

Drawing on the critique in Table 5.3, the question of what might constitute feasible and desirable changes in decision-making can be usefully expanded to consider changes in terms of who participates in deciding the conservation and sustainable use of intertidal mudflats and saltmarshes, how, and when. To reiterate the findings of subsubsection 5.3.1.3, it is certainly clear that a wide range of stakeholders are included in decision-making, and that there are a diverse range of stakes. The crux of the issue, therefore, is not necessarily to do with trying to include more people in decision-making, but with including people in a way that serves to bring about outcomes in decision-making that are more acceptable to a wider range of stakeholders.

Past decisions concerning the conservation and sustainable use of intertidal mudflats and saltmarshes have been made in the context of achieving some other purpose, such as coastal flood and erosion risk management. Furthermore, decisions have been made behind closed doors, in the first instance by those responsible for deciding the 'preferred option' and ultimately by local or national government bodies and their advisors in deciding whether to approve the preferred option. The process appears to have been driven by data generated from numerous scientific studies and public consultation. During consultation, a vast range of stakeholders supported and contested both the data and decisions regarding the preferred option by direct lobbying and through the media, but it is difficult to identify how such studies and public responses influenced the final decision, and to what extent risks and uncertainties were taken into account.

The evidence presented in this study contests that it might be better if decision-making serves explicitly to conserve and sustainably use intertidal mudflats and saltmarshes, with decisions and actions undertaken concertedly by a representative group of stakeholders in an open, robust process based on systems thinking and practice, in which it is clear how the perspectives of those involved have been taken into consideration throughout the process and accounted for in the outcome(s). This involves redrawing (or re-negotiating) the boundaries between decision-makers and those affected by the outcomes. It requires a preparedness to share the power of decision-making, and to enter into a partnership

Table 5.3 Critical systems heuristics in evaluation mode used to compare what 'is' the role of consultation and participation in the Solent decision-making situation with what it 'ought to be' in an improved decision-making situation (adapted from: Ulrich, 1983, 2000)

		Social roles (stakeholders)	Role-specific concerns (stakes)	Key problems (stakeholdings)
		1. Beneficiary / client	**2. Purpose**	**3. Measure of success**
Sources of motivation	'is'	UK Government and maritime industries	To provide a seal of approval for the preferred option	Public acceptance of the preferred option and improvements in the marine and coastal environment
	'ought'	UK citizens as individuals, groups and larger organizations	To accommodate multiple partial perspectives in the decision-making process	Actions meet the requirements and expectations of UK citizens and leads to continuous improvement in the situation
	critique	Values underpinning participation should be robust and transparent as well as foster and encourage stakeholder involvement to achieve more meaningful outcomes in decision-making.		
		4. Decision maker	**5. Resources**	**6. Decision environment**
Sources of control	'is'	Principally UK Government bodies, but influenced by stakeholder consultation	Environmental policies and funding for environmental projects	EU legislation, budget for research studies and consultation, Parliamentary time
	'ought'	A representative body including a diverse range of stakeholders	All resources need to serve meaningful participation	Transparent EU and national policies and budget/time for the decision-making process
	critique	Participation should be controlled democratically, rather than by those with a vested interest in a particular outcome to ensure that resources are used to achieve an equitable outcome.		
		7. Expert	**8. Expertise**	**9. Guarantor**
Sources of knowledge	'is'	Professional consultants appointed by the Government and coastal / maritime industries	Multidisciplinary, but skewed towards scientific and economic	Number of laypersons informed by professionals through consultation
	'ought'	A range of stakeholders with knowledge about the situation, to include systems practitioners as well as other professionals and laypersons	Transdisciplinary, equity between all disciplines, particularly social, economic and environmental	Awareness of how the problem or opportunity has been framed and a good understanding of the impact that participation may have on decisions
	critique	Participation should be a platform for developing mutual understandings of the situation and for changing practices leading to actions to improve the situation, rather than a means of transferring knowledge between experts and laypersons.		
		10. Witness	**11. Emancipation**	**12. Worldviews**
Sources of legitimacy	'is'	Environmental NGOs, individual citizens	Questionable use of deliberative processes	Consultation is a means of voicing opinions on the preferred option
	'ought'	Those affected by the outcomes of the decision-making situation in the past, present and future, plus appropriate advocates for non-human entities	Genuine invitation and encouragement to participate to all witnesses with the option to decline without fear of coercion.	A systemic and systematic approach is required to achieve better outcomes in decision-making, which accommodate multiple perspectives
	critique	Participation should: invite the involvement of a diverse range of stakeholders; be seen to acknowledge that there will always be 'winners' and 'losers' in environmental action initiatives; and aim to develop shared understandings and practices leading to change, rather than be a means of voicing opinions on the preferred option.		

— or community of practice — which recognizes many different types of knowledge and experiences, and within which common understandings and practices to conserve and sustainably use intertidal mudflats and saltmarshes can be forged through dialogue.

5.3.8 Take actions

Bearing in mind the emphasis that has been placed on the need to consider multiple diverse perspectives in decision-making, and the need for interactions between stakeholders in the form of social learning to bring about change, it seems relevant that the next stage of research should invite stakeholders in the Solent to participate in a pilot study of the 'improved' decision-making process and provide feedback on its performance in terms of efficacy, efficiency and effectiveness. This will enable refinement of the decision-making process, justify its use in current and future decision-making situations, and perhaps bring about concerted actions by those involved to address the wider problem of intertidal mudflat and saltmarsh conservation and sustainable use across the Solent.

5.4 Conclusions

The research presented in this chapter used multi-methodology systems intervention as a lens through which to understand decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes, and to recommend changes to improve the decision-making process through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken.

The study found that the decision-making process fails to start out systemically, and that an emphasis on participation through consultation is perhaps not the best means of involving stakeholders. The gradual 'closing down' of options as a result of the above, means that there is often inaction or delays in taking actions due to multiple diverse perspectives regarding what action is required, how, why and by who. Improvements have been suggested involving a social learning cycle based on systems thinking and practice, in which stakeholders engage in dialogue and work together to make decisions and take actions towards the conservation and sustainable use of intertidal mudflats and saltmarshes. A pilot study is proposed in order to evaluate the performance of the 'improved' decision-making process from the perspective of those involved, further refine it, and justify its use in current and future decision-making situations.

As with the works in chapter 4, the concepts and methods applied in this study are transferable to other complex decision-making situations in the UK and elsewhere, such as those concerning spatial planning, green infrastructure, transportation and energy use, in which there is a potential need to better understand what the problem is and what can be changed to improve it.

Chapter 6

Lessons from a multi-methodology systems intervention to improve the conservation and sustainable use of intertidal mudflats and saltmarshes

6.1 Introduction

Evidence presented in chapter 5 shows that decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes fails to start out systemically, and that an emphasis on participation through consultation is perhaps not the best means of involving stakeholders. The gradual 'closing down' of options as a result of this process means that there is often inaction or delays in taking actions due to multiple diverse perspectives regarding what action is required, how, why and by who. The study recommended changes in the decision-making process based on a social learning cycle, in which stakeholders engage in dialogue and work together using techniques and skills in systems thinking, modelling, negotiating and evaluating as heuristic devices to bring about more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes.

Building on the work in chapter 5, the purpose of the research presented in this chapter was to implement changes (perceived improvements) in the decision-making process and evaluate the outcomes. To this end, a pilot study was undertaken in the Solent. This chapter describes the research method, then presents and discusses the results of the study and its implications.

6.2 Data and methods

The pilot study comprised a one-day workshop entitled *Sustainable mudflats and saltmarshes: from systemic understanding to systemically feasible and desirable actions*. It was held on Wednesday 10th October 2012 at the University of Southampton. It was the first known time that stakeholders have been brought together explicitly for the purpose of collectively making decisions and taking actions to improve the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent.

6.2.1 Participants

Local stakeholders were invited to participate in the workshop using an iterative technique. Initially, seven stakeholders identified through existing networks developed during previous research were invited (Table 4.1). These stakeholders were then asked to suggest who, in addition to themselves, they thought should be invited. Invitations were then sent to these additional people, who in turn were asked to suggest further participants. In some cases, specific people were named, and in others, only broader stakeholder groups such as local authorities and NGOs were suggested. In the latter case, it was necessary to determine the specific stakeholders to be invited within the suggested stakeholder groups. The stakeholder analysis in Figure 5.4 was primarily used for this purpose.

The invitation process continued until there were no further stakeholders or stakeholder groups suggested. Approximately 100 potential participants were directly invited in this way. A small number of potential participants were invited indirectly via stakeholders who forwarded their invite to others such as work colleagues and friends, particularly in cases where the original invitee could not attend the workshop. The potential participants were in almost all cases invited via email, which facilitated both the direct and indirect invitation process. A participant information sheet and consent form was provided to make explicit both the purpose of the study and the expectations of the participants (Appendix D). Participants from all major stakeholder groups identified were represented at the workshop (Table 6.1). The only notable omission was a representative from the Marine Management Organization, who were considered key stakeholders by those involved in the decision-making process. The Marine Management Organization were invited to participate, but declined to attend the workshop.

6.2.2 Workshop format

The one-day workshop comprised an informal introduction, a series of four highly interactive working sessions, and an evaluation session (Table 6.2). The duration of the workshop was primarily decided based on stakeholder feedback regarding the length of time perceived necessary or available in which to address the issue of intertidal mudflat and saltmarsh conservation and sustainable use in the Solent. This inherently involved

Table 6.1 Stakeholder representation at the Solent decision-making workshop

Stakeholder group	Organization	Name	Role
Government bodies	Natural England	Graham Horton	Marine Lead Advisor, Southern Seas Team
	Environment Agency	Adam Cave	Biodiversity Technical Specialist, Solent Fisheries and Biodiversity team
	English Heritage	Peter Murphy	Coastal Strategy Officer
Local authorities	Southampton City Council	Lindsay McCulloch	Planning Ecologist
	Eastleigh Borough Council	Gemma Christian	Planner
	Havant Borough Council	Gavin Holder	Eastern Solent Coastal Partnership
Environmental NGOs	RSPB	Tim Callaway	RSPB Area Manager (Hants, Isle of Wight and Berks)
	Hampshire and Isle of Wight Wildlife Trust	Clive Chatters	Head of Conservation — Policy and Evidence
Consultants	ABPmer Ltd	Colin Scott	Managed Realignment and Environmental Impact Assessment Specialist
	MarineSpace Ltd	Dafydd Lloyd-Jones	Technical Director, ex-National Oceanography Centre, co-author on Solent beneficial use scoping study
	Lymington Technical Services	Paul Tosswell	Director
Academics	University of Southampton	Malcolm Hudson[a]	Lecturer, works on interdisciplinary projects with a focus on human impacts on natural systems
		Susan Hanson	Researcher, interested in coastal geomorphology, shoreline management and the adaptation of coastal systems to climate change
	National Oceanography Centre, Southampton	Carl Amos	Professor, specialism in sediment dynamics and coastal morphodynamics
Harbour Authorities	Lymington Harbour Commissioners	Ryan Willegers	Harbour Master / CEO
	River Hamble Harbour Authority	Alison Fowler	Environment and Development Manager
	QHM Portsmoth	Rob Whitworth	Lt Cdr RN, QHM Portsmouth conservation representative
Shipping Companies	Wightlink Ltd	John Burrows	Operations Director, leads on saltmarsh issues for Wightlink
General public	North Solent Coastal Group	Susan Campbell	Landowner
		Mike Kleyn	Landowner
	Jacobs consultancy	Jack Coughlan	Ex-marine biologist for Central Electricity Generating Board, and ex-Hampshire and Isle of Wight Wildlife Trust trustee (1975, 1981, 2008)

[a] Dr. Malcolm Hudson is a supervisor of the research presented in this thesis. However, he did not participate in the workshop in his supervisory role, but rather as a researcher and lecturer with relevant knowledge and experience of the Solent problem situation.

striking a balance between making the workshop duration long enough to achieve meaningful outcomes, yet short enough to enable stakeholder participation. The four working sessions were based on the concepts and techniques for an 'improved' decision-making process recommended in chapter 5. They were designed to actively engage participants in systems thinking, modelling, negotiating and evaluating in order to explore the situation, formulate problems and opportunities, identify feasible and desirable changes, and take informed actions. The techniques used in the working sessions, and the purposes for their use, are explained where appropriate in section 6.3. The evaluation session incorporated a debrief of the working sessions and the completion of an evaluation questionnaire by the participants (Appendix E).

Table 6.2 Workshop schedule

Time	Session	Objectives	Techniques
0900	Registration	Issue name badges and consent forms	
0915	Introduction	Disseminate emergency information (e.g. fire escapes, emergency telephone number)	
0930	Working session 1	Explore the situation	Rich pictures, systems map
1030	Refreshment break		
1045	Working session 2	Formulate problems, opportunities and systems of interest	BATWOVE and root definitions
1230	Lunch		
1330	Working session 3	Identify feasible and desirable changes	System dynamics model, multi-criteria decision analysis
1430	Refreshment break		
1445	Working session 4	Plan actions to improve the situation	Conceptual models
1600	Evaluation	Summary and evaluation questionnaires	

It was assumed that the participants had at least some knowledge and experiences of the issues associated with intertidal mudflat and saltmarsh conservation and sustainable use in the Solent, but no prior knowledge or experiences in using systems techniques. Thus, a brief explanation and an example of the relevant technique(s) was given before each task in the working sessions. The examples were taken from Open University textbooks (Open University, 2006a,b,c,d,e) and were deliberately unrelated to the workshop context so as to not influence the participants' responses to the tasks. The researcher acted as facilitator throughout the workshop, attempting to guide the participants through activities and discussions in a timely manner without influencing the content of materials produced or the information generated and debated in discussion.

6.3 Results and discussion

Sections 6.3.1 to 6.3.5 report on each of the four working sessions and the evaluation session respectively, providing a summary of the tasks undertaken and the outcomes.

6.3.1 Working session 1: Explore the situation

The first working session focused on developing systemic awareness of the perceived problem situation by exploring and depicting the participants' situation of interest using rich pictures, and defining the participants' system of interest using a systems map.

6.3.1.1 Rich pictures

Working together in small groups, the workshop participants created four rich pictures (one per group) depicting the main actors and elements in the Solent problem situation and the relationships between them (e.g. Figure 6.1). Subsequently, the participants were asked to introduce themselves to the other participants and, using their rich picture as a visual aid, to describe in about one minute the issues that they perceived to be important in the context of intertidal mudflat and saltmarsh conservation and sustainable use in the Solent. The aim here was to capture their perspective of the situation and to communicate

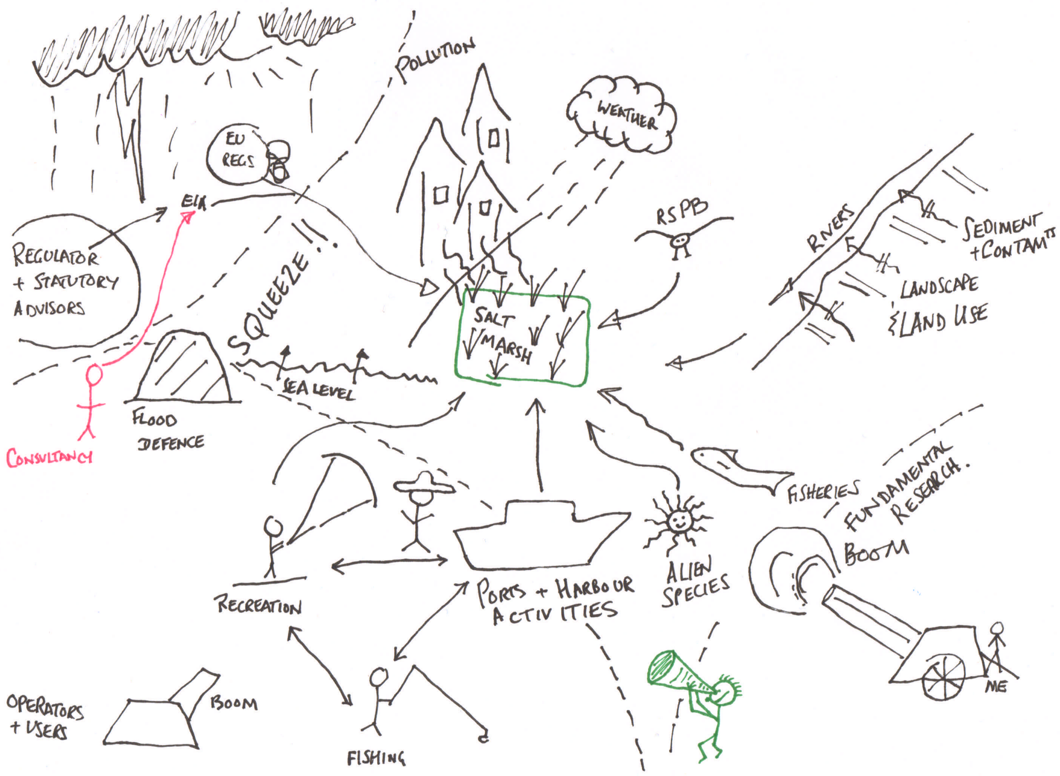


Figure 6.1 Solent problem situation from the perspective of a group of the workshop participants

it to others. Furthermore, to start the process of thinking systemically about the problem situation — viewing it from multiple perspectives — and to initiate dialogue between the participants.

The rich pictures revealed many different facets of the problem situation: commercial and leisure users carrying out activities within the situation, e.g shipping, fishing, kite surfing and bird watching; central government bodies, local authorities and their advisors governing activities such as dredging and port expansion; non-governmental organizations campaigning for or against activities such as the managed realignment of coastal defences; consultants engaged in assessing the impacts of various activities; academics investigating existing and new activities, e.g. *Spartina* die-back; and local residents affected by but not necessarily involved in the activities, such as land owners concerned or affected by coastal erosion and flooding. Furthermore, the process of collaboratively creating the rich pictures in small groups was particularly effective in terms of initiating and engaging the participants in dialogue *with each other* about the problem situation. However, as a result of this process, the rich pictures were perhaps not as detailed as those in previous studies, in which a single rich picture representing the problem situation was created by the researcher in conjunction with participants via interviews (e.g. Bjerke, 2008; Luckett *et al.*, 2001; Maqsood *et al.*, 2001) or facilitated discussion (e.g. Bunch, 2003). Nonetheless, they enabled the participants not only to voice their own perspective, but also to see the problem situation from a variety of different partial perspectives, and to appreciate and learn from the different perspectives because of the different insights into the problem situation that they evoked.

6.3.1.2 Systems map

During and based on the participants one-minute descriptions of the problem situation, the researcher compiled the named stakeholders and issues into a systems map (Figure 6.2) which was collectively discussed and amended as perceived necessary by the participants. The immediate aim was to define the structure and boundary of the participants' system of interest, identifying the actors and elements incorporated within the system, and those in its environment which affect it and are affected by it. In doing so, the intention was to further develop the participants' systemic awareness, working towards achieving a shared understanding of the system of interest.

The systems map brought together the actors and elements in the problem situation which the participants perceived to be important. As with the rich pictures and the other

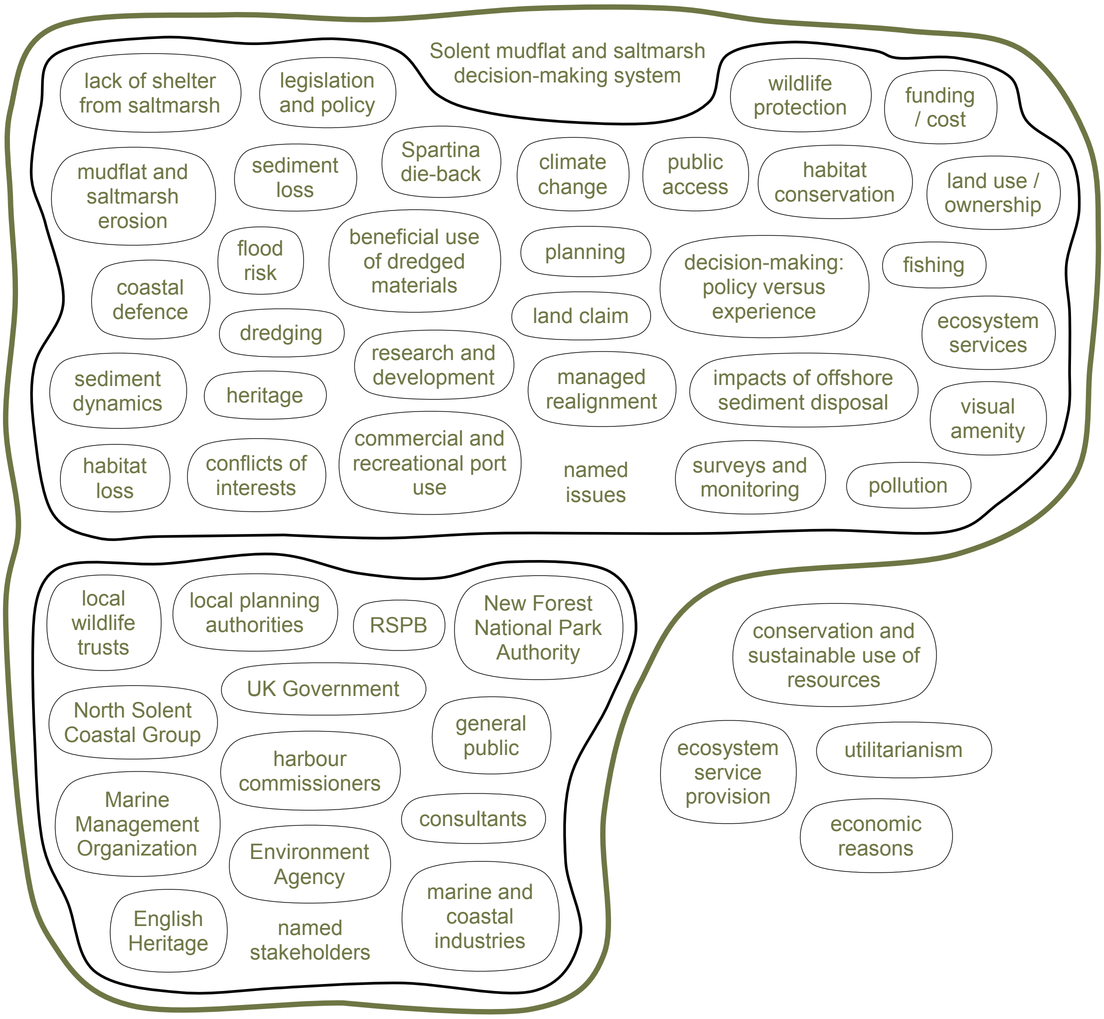


Figure 6.2 Solent system of interest from the perspective of the workshop participants (redrawn from the version created at the workshop)

models created during the workshop, it is a simplified representation of the problem situation from the participants' perspectives. It does not dwell on the details of the situation. For example, it does not group together 'campaigners' such as Wildlife Trusts and the RSPB or other stakeholder groups, nor detail specific legislation and policies of interest, although this could be done in a second iteration. However, even in the most simple format, it created space for reflective thinking and debate about the situation as a whole using systems concepts such as boundaries and levels (system, sub-systems and environment), leading to new insights and understandings. In particular, it led to the modification of the system of interest to include additional actors and elements, and surfaced the worldviews which justify and attribute meaning to the system. Perhaps most importantly, it implicitly developed shared understandings of the problem situation, and served to inform subsequent tasks in the workshop.

6.3.2 Working session 2: Formulate problems, opportunities and systems of interest

The second working session focused explicitly on developing shared understandings by identifying the key parts of the participants' system of interest using BATWOVE analysis, and formulating a concise description the system of interest using root definitions.

6.3.2.1 BATWOVE and root definitions

Working together in groups, the participants identified the key parts of the system of interest from Figure 6.2 using the mnemonic BATWOVE, and formulated three root definitions (one per group) incorporating all of the key parts. Subsequently, by facilitated discussion, the root definitions were debated and amended until a 'preferred' root definition was collectively agreed (Table 6.3). The aim here was not only to provide a base from which to identify feasible and desirable changes to improve the problem situation, but also to alleviate clashes of perspective and purpose that can lead to conflict when identifying such changes, or inaction because there is no agreement on *what* the objective of intervention is, *how* it should be achieved and for what purpose (*why*).

Table 6.3 BATWOVE and root definition applied to the Solent problem situation by the workshop participants (redrawn from the version created at the workshop)

Beneficiaries	Coastal communities, commercial and leisure users, flora and fauna
Actors	Policy makers, regulators, coastal developers, researchers, commercial and leisure users, environmental interest groups, coastal communities
Transformation	Disjointed management $\rightarrow$ sustainable, integrated management
Worldview	Ensure the provision of saltmarsh and mudflat functions and services
Owners	Policy makers, regulators, coastal developers, researchers, commercial and leisure users, environmental interest groups, coastal communities
Victims	Other habitats and species, e.g. coastal grazing marsh, birds
Environment	Funding, time constraints, legislation and policies, lack of information
Root definition	'A sustainable system to manage saltmarshes and mudflats, by effective and timely decision-making informed by scientific evidence, in order to achieve realistic, positive outcomes for the conservation of saltmarsh and mudflat functions for the benefit of present and future generations'

Albeit that each of the groups used slightly different wording within their BATWOVE analyses and root definitions, they were essentially in agreement about the long-term aim (W) and immediate objective (T) of intervention, as well as about the persons involved (BAOV) and the constraints imposed upon it (E). Thus, the participants had little difficulty in collectively formulating the 'preferred' root definition, which was adapted from one of the root definitions formulated by the groups. It was acknowledged that further iterations could have improved the root definition, for example, by making explicit *all* of the key parts identified in the BATWOVE analysis. But, nonetheless, together with the rich pictures and systems map, it sufficed to bring about for the first known time a common understanding and shared expression of the situation from which feasible and desirable changes (improvements) were later identified.

6.3.3 Working session 3: Identify feasible and desirable changes

The third working sessions shifted the focus of the workshop towards identifying feasible and desirable changes in the participants' situation of interest by scrutinizing potential future intertidal mudflat and saltmarsh management scenarios using a system dynamics simulation model, and comparing the potential scenarios using multi-criteria decision analysis.

6.3.3.1 System dynamics model

A system dynamics model was pre-constructed by the researcher to simulate four possible future intertidal mudflat and saltmarsh management scenarios: do nothing, business as usual, managed realignment, and beneficial use of dredged materials (see Appendix F for the full model and documentation). Prior to the working session, participants were given the opportunity to engage with the model in order to gain an appreciation of the inherent assumptions and limitations. During the working session, the outputs from the model (e.g. Figure 6.3) were used to stimulate dialogue between the participants about what *might* happen if current practices continue or if specific changes are instituted. The immediate aim was to facilitate understanding about the environmental, social and economic consequences of different management interventions, and to inform the process of identifying feasible and desirable changes in the situation of interest.

The model generated important insights into the four possible future management scenarios, showing significant differences between them, particularly in terms of the economic costs and the impacts on saltmarsh extent over the lifetime of the scenarios. For example, as shown in Figure 6.3, it revealed that the cost of 'business as usual' is significantly more in the long-term than the alternative scenarios (assuming that there are no costs associated with mitigating the loss of urban or natural habitats and species such as coastal grazing marsh under 'managed realignment' or 'do nothing' scenarios). The process of scrutinizing the four scenarios also raised pertinent issues concerning, for example, protection of people and property from coastal flooding and erosion, conservation of habitats and species both to landwards and seawards of coastal defences, ability to meet

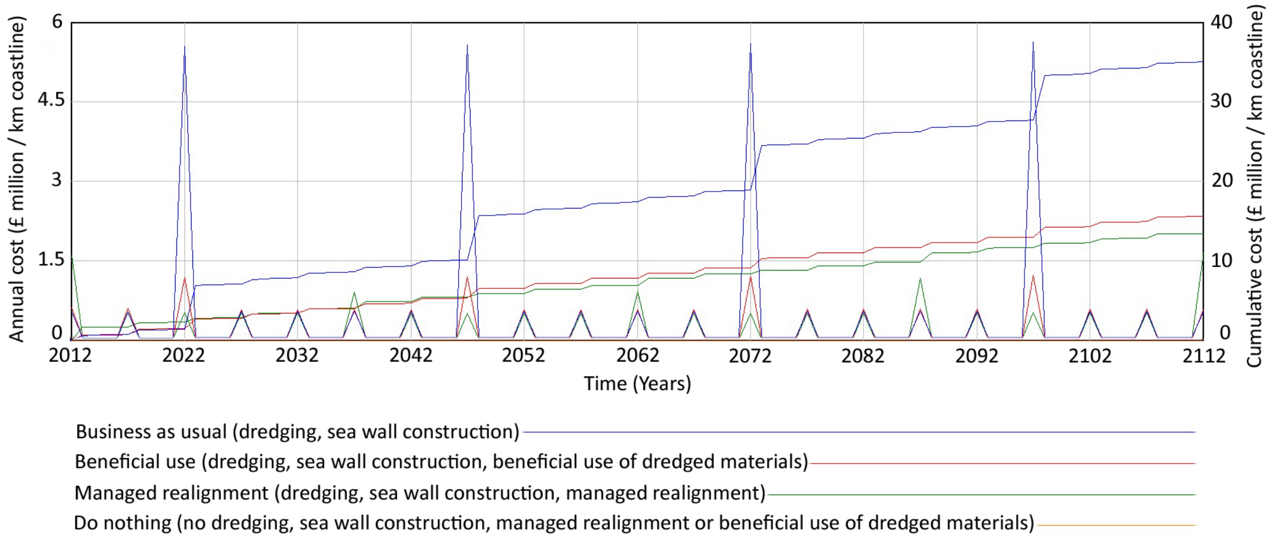


Figure 6.3 VENSIM™ simulation showing a comparison of the economic costs of possible future management scenarios. The model used 'best guess' estimates for input values. However, it must be taken into consideration when interpreting the results that the model does not account for the costs of relocating urban or natural habitats under 'managed realignment' or 'do nothing' scenarios.

(conflicting) legislative and policy obligations, technical feasibility, economic viability, and reliability of outcomes. Thus, whilst the model may be open to criticism on account of the assumptions and value judgements made as a part of the modelling process, it enabled the environmental, social and economic impacts of possible future interventions to be more fully understood by the workshop participants, and promoted objective debate based on shared understandings about feasible and desirable changes in their situation of interest.

6.3.3.2 Multi-criteria decision analysis

Having scrutinized the possible future management scenarios, the participants worked together to establish criteria for assessing the extent to which the aim and objective for intervention (described in subsubsection 6.3.2.1) would be met if the scenarios were implemented. Then, by facilitated discussion and consensus, each criterion was given a weight (0–1) to reflect its perceived importance relative to the other criteria, and each option was given a score (1–10) for the extent to which it satisfied each of the criteria. The scores for each option were then multiplied by the appropriate weights to give weighted scores, which were then totalled for each option to give an overall score (Table 6.4). Normally, the option with the highest score is regarded as the 'preferred option' (Open University, 2006e). However, the immediate aim here was not necessarily to identify a single preferred option, but rather to enable the participants to make informed judgements and to engage in dialogue about the feasibility and desirability of possible future management interventions in the context of their situation of interest.

Table 6.4 Multi-criteria decision analysis applied to four possible future management scenarios

Criteria	Weight	Do nothing		Business as usual		Managed realignment		Beneficial use	
		Score	Weighted score	Score	Weighted score	Score	Weighted score	Score	Weighted score
Meets legislative requirements	0.9	6	5.4	5	4.5	6	5.4	6	5.4
Financially viable	0.9	8	7.2	2	1.8	6	5.4	5	4.5
Protection of people and property	0.8	1	0.8	9	7.2	5	4.0	9	7.2
Protection of biodiversity	0.7	2	1.4	3	2.1	6	4.2	5	3.5
Reliability of outcome	0.6	10	6.0	7	4.2	6	3.6	5	3.0
Technically feasible	0.6	10	6.0	9	5.4	9	5.4	8	4.8
Democratic accountability	0.5	3	1.5	7	3.5	4	2.0	7	3.5
Time-frame	0.5	10	5.0	5	2.5	4	2.0	5	2.5
Overall score			**33.3**		**31.2**		**32.0**		**34.4**

The outcomes from the multi-criteria decision analysis reiterated that no single option is better than the alternative options for all criteria; each has advantages and disadvantages requiring environmental, social and economic trade-offs. After deliberations, 'managed realignment' and 'beneficial use' were selected as the options which potentially best meet the aim and objective for management intervention in the problem situation. The participants agreed that these options were more economically feasible than 'business as usual', and more environmentally and socially desirable than 'do nothing'. Thus, they were both put forward for further consideration in the subsequent working session. However, whilst it is acknowledged that the task created space for the participants to (re-)evaluate and articulate their value positions, and to compare different options and the values expresses by other participants in a transparent way (Open University, 2006c), it is questionable (from the perspective of the researcher with the benefit of hindsight) whether the insights gained relative to the time taken to complete the task justify its use in future workshops of a similar duration; the time could perhaps have been better allocated to further discussions in the fourth working session (see subsection 6.3.4).

6.3.4 Working session 4: Take actions

The fourth working session focused explicitly on identifying and enabling concerted actions to continuously improve the participants' problem situation by making conceptual (system) models relevant to realizing feasible and desirable changes (see subsection 6.3.3), and using the models to inform and structure discussion about the situation and the actions required to improve it.

6.3.4.1 Conceptual models

Working together in groups, the participants created three conceptual models (one per group) representing the sequence of activities that would have to be undertaken if the future management scenarios which they perceived to be both feasible and desirable ('managed realignment' and/or 'beneficial use') were to be realized (e.g. Figure 6.4). Then, via facilitated discussion, the conceptual models were compared with each other, and with the real-world problem situation, by asking pertinent questions such as: If this activity missing in the real-world, is that a good thing? Does it matter? What are the implications of filling a gap? How might it be filled? (Checkland, 1985). The purpose of the task was to engage the participants in further discussions about the problem situation, and to identify the immediate actions necessary to improve it.

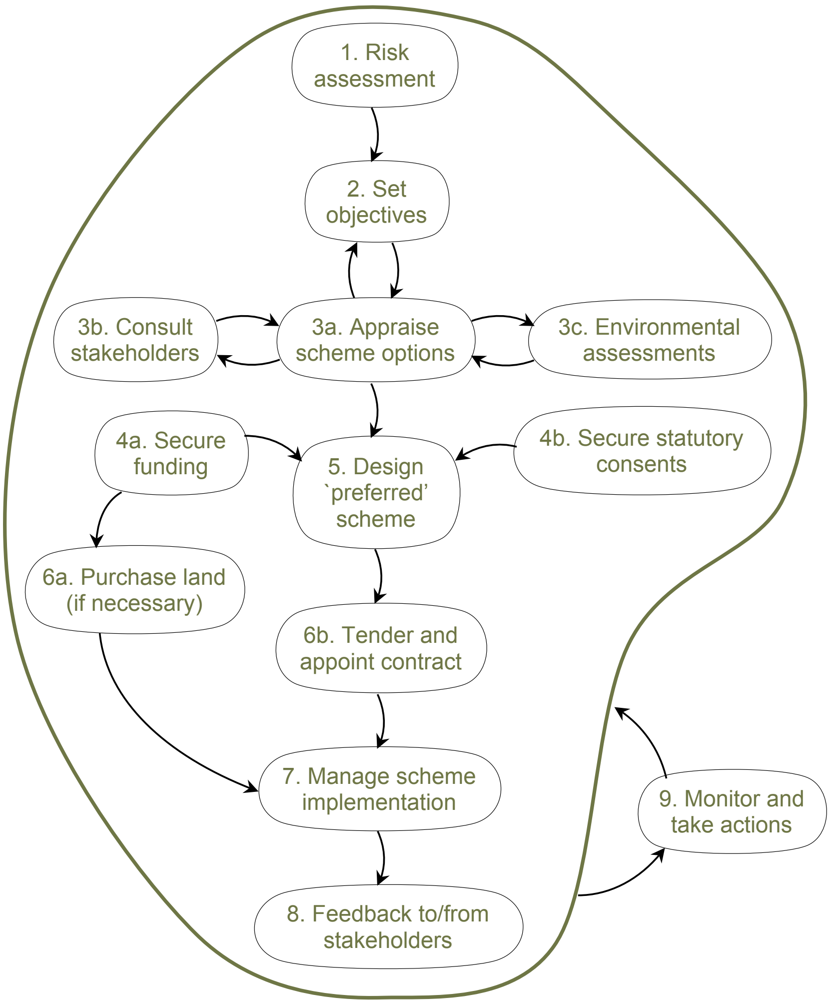


Figure 6.4 Sequence of activities that would have to be undertaken if the future management scenarios which were perceived to be both feasible and desirable were to be realized (redrawn from the version created by a group of workshop participants)

The conceptual models encapsulated and visualized the participants' thinking about the activities required to bring about feasible and desirable future management scenarios.

It is notable that in many ways the models mirrored the happenings in the real-world problem situation; this is not surprising since both managed realignment and beneficial use schemes have been undertaken in the Solent, albeit on an insufficient scale to bring about significant improvements in the problem situation (see chapter 4). Perhaps consequently, some of the participants seemed to struggle with modelling the conceptual system of interest rather than the real-world situation of interest, or else inadvertently slipped into modelling the real-world situation, requiring some guidance from the researcher to steer them in the right direction. Nonetheless, the process of making comparisons between the models and the real-world problem situation identified four major differences with significant implications in terms of taking actions-to-improve:

- the models implied a fundamental shift in concept and purpose, from a reactive to a proactive approach to management intervention;
- a relationship between stakeholders is implied which requires a richer stakeholder dialogue, and hence for stakeholders to be more self-motivated and committed to working together to achieve the aim and objectives of management intervention;
- structures and processes would need to be developed which enable the system to function as intended, including: (1) the establishment of an open-access knowledge base, e.g. a central repository of relevant research and other data, and (2) a scheme which links together and enables constructive dialogue between stakeholders with potential resources, e.g. dredged materials, and stakeholders who might be able to use them;
- a more organized monitoring and control of the activities is implied.

There was not enough time to discuss these points in detail; and with the benefit of hindsight, it is strongly suggested that sufficient time is allocated in which to do so in similar future workshops. However, from limited discussions, it became clear that there are some actions which the workshop participants can take to improve the problem situation, but others which require active collaboration with others. For example, the participants perceived that they could (and should) take concerted actions in terms of being more self-motivated and committed to working together to achieve the aim and objective for management intervention, but also that the Marine Management Organization should be involved in establishing the necessary schemes which support and enable the system to function. Thus, the next steps should incorporate a discussion of the outcomes from the workshop with the significant others.

6.3.5 Evaluation session: Participants' feedback

The evaluation session comprised a short summary of the workshop by the researcher, followed by the completion of questionnaires by the workshop participants. The purpose of the questionnaires was to evaluate the performance of the decision-making process from the participants' perspectives, and to identify further improvements and areas of application. The questionnaires obtained qualitative feedback via seven open-ended questions. Responses were received from 13 of the 21 workshop participants. The method of analysis involved four steps: (1) collating the responses to each question in a database; (2) analysing the responses to each question and identifying common themes; (3) assigning codes to the common themes and coding each response appropriately in the database; and (4) calculating the number of responses per code for each question and evaluating the outcomes. The following sections present a summary of the participants' responses.

6.3.5.1 Efficacy, efficiency and effectiveness (Questions 1–3)

The first 3 questions asked the participants to judge the decision-making process against three measures of performance[1]:

1. Efficacy — Did it achieve its immediate purpose — to enable the participants to make informed decisions?
2. Efficiency — Did it make the best use of resources such as time?
3. Effectiveness — Did it achieve its overall purpose — to enable concerted actions to improve the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent?

The responses to these questions confirm that the decision-making process generally proved very successful for this group of stakeholders, with only one respondent answering negatively to all three questions (Figure 6.5). The respondents stated that the 'workshop was very useful' and 'seemed to work very well'. Furthermore, that the root definition formulated in the second working session was particularly useful, and that the final session was the most useful and 'it would have been helpful to carry this on further'. However, a number of respondents also stated that 'it was a long day'. The main area of concern unsurprisingly related to the need to follow-up on the outcomes from the workshop in order to bring about improvements in the problem situation, especially since the Marine Management Organization did not attend.

[1] initially proposed and developed by Forbes and Checkland (1987)

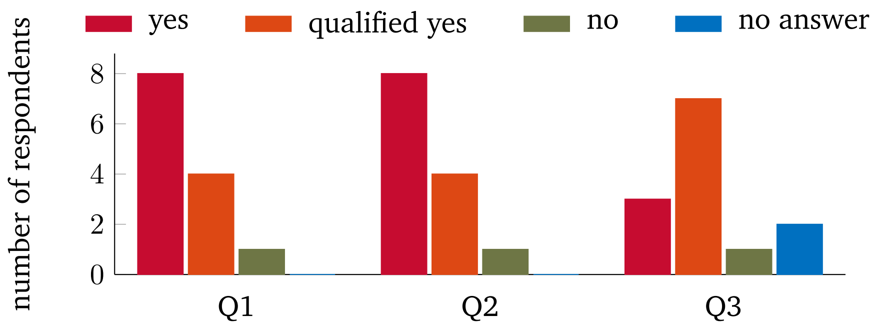


Figure 6.5 Participants' responses to questions 1–3 of evaluation questionnaire (coded)

6.3.5.2 Modifications (Question 4)

Participants were asked to suggest ways in which the decision-making process could be further improved. Respondents suggested 10 different improvements, which fall into three categories: structures and processes of management interventions; stakeholder involvement in management interventions; and external influences on management interventions (Table 6.5).

Table 6.5 Participants' responses to question 4 of evaluation questionnaire (coded)

Participants' responses	Number of responses[a]
Structure and processes of management interventions	
More focus on developing shared understandings and practices	2
Repeat meetings/workshops	1
Presumption for 'deploy and monitor'	1
Stakeholder involvement in management interventions	
Richer stakeholder dialogue	3
More involvement from statutory bodies	1
More involvement from landowners/managers	1
Clear guide/lead authority to enable and validate decisions	1
Better incentives	1
External influences on management interventions	
Better science to give greater confidence in decision-making	1
Data sharing	1

[a] Some participants suggested a number of different improvements, all of which have been taken into account in the number of responses stated

The responses generally reiterate the outcomes from the final working session (subsection 6.3.4). However, there are three key points which merit further consideration. First, the participants felt that stakeholders should be involved as much as possible in the decision-making process, and in particular, that there should be more involvement from statutory bodies as well as from coastal landowners and managers. Furthermore, that there should be a designated body to facilitate and guide the decision-making process through the various stages. Second, the decision-making process should focus less on analysing the options for future management interventions, and more on developing shared understandings and practices to bring about management interventions. Third, repeat meetings/workshops are necessary to ascertain whether decisions and actions are bringing about continuous improvement in the problem situation, and to take control actions if necessary.

6.3.5.3 Areas of application (Questions 5–6)

Participants were asked whether the decision-making process was appropriate in this context, and in what future contexts it could also be applied. The responses to the first of these questions confirm an overall view that the decision-making process was appropriate for these stakeholders, with half of the respondents stating an unqualified 'yes', and the others a qualified 'yes' (Figure 6.6). The qualifications mentioned included an observation that site specific issues could lead to different outcomes (and this is to be expected), and the need to allocate more or less time to certain tasks in the workshop.

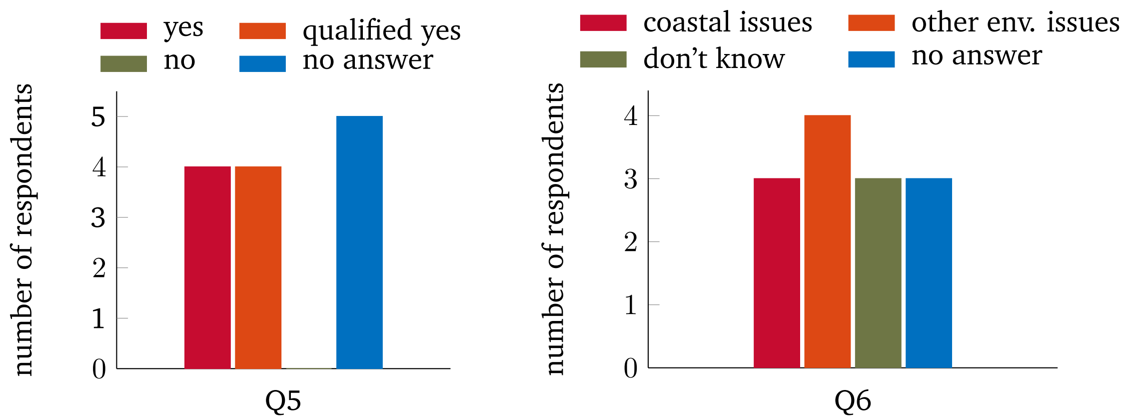


Figure 6.6 Participants' responses to questions 5–6 of evaluation questionnaire (coded)

The responses to the second of these questions fall into three categories: coastal issues, including intertidal mudflat and saltmarsh conservation and sustainable use; other environmental issues; and those in which the respondent was uncertain as to possible future applications (Figure 6.6). The respondents felt that the decision-making process could potentially be used at a local, regional and national scale in the context of intertidal mudflat and saltmarsh conservation and sustainable use, particularly for 'beneficial use' reparation schemes; and also in other coastal and environmental decision-making situations in which there are multiple diverse perspectives, including green infrastructure and nuclear power. The uncertainty of some of the respondents regarding possible future areas of application can perhaps be attributed to the new and different nature of the decision-making process used in the workshop.

6.3.5.4 Further comments (Question 7)

The final question presented the opportunity for participants to make any further comments, and the responses generally provide a pleasing conclusion to this analysis of their feedback. One respondent reiterated concerns regarding public information, legislation and funding issues. The other respondents who answered this question thanked the researcher for the invitation to participate in the workshop, or else stated either 'well done' or 'best of luck with further research'.

6.4 Conclusions

The research presented in this chapter used a pilot study workshop in the Solent to implement and evaluate changes (perceived improvements) in decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes.

The outcomes demonstrate that the 'improved' decision-making process generally proved very successful for this group of stakeholders. It engaged them in dialogue and in working together using skills and techniques in systems thinking, modelling, negotiating and evaluating, leading to new insights and shared understandings about the problem situation, and concerted actions to improve it.

Notwithstanding that there are some refinements that can be made to further improve the decision-making process as a result of 'lessons learned' from the workshop, the participants feedback confirms that it was appropriate in this context and may also be useful in other complex situations, particularly those involving multiple stakeholders from diverse backgrounds. However, this raises wider questions about enabling — on a local, national and global scale — the new and different ways of thinking and acting, such as the decision-making process developed in this research, that are clearly necessary to meet the needs of present and futures generations of humans and other species.

Part IV

Conclusions

Chapter 7

Key findings and recommendations

7.1 Introduction

The aim of the research presented in this thesis was to understand and improve decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes, using a case study in the Solent, UK. This chapter summarizes the key findings from the study, its contributions to knowledge, and potential areas of application. It concludes with recommendations for further research.

7.2 Summary of key findings

A review of the UK progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes, presented in chapter 2, found that uncertainties in the current status and trends make it difficult to assess the overall net change in extent across the UK. However, it is apparent that losses due to erosion continue to exceed gains from intertidal mudflat and saltmarsh reparation (IMSR) schemes in south-east and southern England. IMSR schemes in the UK have been generally limited to relatively small-scale trials in comparison to elsewhere in Europe and in the USA. No research to date has unequivocally identified the causes of erosion. Regardless of the cause, the loss of intertidal mudflats and saltmarshes has adverse impacts on the provision of ecosystem services upon which humans and other species depend. The evidence presented in this chapter suggests that alongside further science-based research, there is a need to develop a decision-making process capable of accommodating complexity, uncertainty and multiple diverse perspectives, through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken.

Chapter 3 reviewed multi-methodology systems intervention (MMSI) as a lens through which to view a complex problem situation, and to make decisions and take actions to resolve it. MMSI involves combining systems methodologies in whole or in part. Systems methodologies seek to resolve a problem situation by understanding the relationship between its parts, which enables properties to be observed that cannot be found from the properties of the component parts individually. Thirty years since MMSI came to the fore, discourse continues amongst researchers and practitioners regarding the best ways to choose and apply methodologies, but no research to date has unequivocally resolved this issue. In practice, MMSI is diverse in both context and content, with a variety of systems approaches being frequently employed in combination. However, the use of multi-methodology presents its own problems to researchers and practitioners — philosophically, culturally, psychologically and practically — particularly where combining methodologies from different paradigms is concerned. Nonetheless, MMSI is ultimately both desirable and feasible. Potential avenues for further development in MMSI have been suggested that emerge from this discussion including: (1) the concept of a systems meta-paradigm; and (2) an iterative framework for structuring and organizing intervention and change in a complex problem situation that is compatible with existing meta-methodologies for choosing and linking methodologies. The framework subsequently formed the cornerstone for multi-methodology systems intervention in this study.

The research presented in chapter 4 constructed a timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from the perspective of those involved, in order to establish *what* is actually happening, *why*, *how*, and by *who*. The evidence demonstrates an abundance of research and consultation for legislation and policy development purposes, with a relative lack of practice to actively conserve and sustainably use intertidal mudflats and saltmarshes. The majority of the events identified in this study indirectly influenced the conservation and sustainable use of intertidal mudflats and saltmarshes, and were primarily concerned with some other purpose, such as coastal flooding and erosion risk management, and dock development. Research, legislation and policy, and practice are interconnected in a complex web, with changes in one domain being reflected in another. Yet despite the significant investment in research and consultation processes by many people over numerous years, no clear end point appears to have been reached in terms of realizing intertidal mudflat and saltmarsh conservation and sustainable use.

Building on the findings of chapter 4, the research presented in chapter 5 used multi-methodology systems intervention as a lens through which to view and make sense of what the existing decision-making process is, and how to intervene to change (improve) it. Specifically, it operated a framework for environmental decision-making using a combination of techniques derived primarily from three systems approaches: soft systems methodology, system dynamics and critical systems heuristics. The study found that the decision-making process fails to start out systemically, and that an emphasis on participation through consultation is perhaps not the best means of involving stakeholders. The gradual 'closing down' of options as a result of the above means that there is often inaction or delays in taking actions due to multiple diverse perspectives regarding what action is required, how, why and by who. An improved decision-making process is suggested involving a social learning cycle based on systems thinking and practice, in which stakeholders engage in dialogue and work together to make decisions and take actions towards the conservation and sustainable use of intertidal mudflats and saltmarshes.

Based on the findings from chapter 5, the research presented in chapter 6 used a pilot study workshop in the Solent to implement and evaluate changes (perceived improvements) in decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes. The outcomes demonstrate that the improved decision-making process generally proved very successful for this group of stakeholders. It engaged them in dialogue and in working together using skills and techniques in systems thinking, modelling, negotiating and evaluating, leading to new insights and shared understandings about the problem situation, and concerted actions to improve it. Notwithstanding that there are some refinements that can be made to further improve the decision-making process as a result of 'lessons learned' from the workshop, the participants' feedback confirms that it was appropriate in this context and may also be useful in other complex situations, particularly those involving multiple stakeholders from diverse backgrounds. However, this raises wider questions about enabling — on a local, national and global scale — the new and different ways of thinking and acting, such as the decision-making process developed in this research, that are clearly necessary to meet the needs of present and futures generations of humans and other species.

7.3 Contributions to knowledge

The new contributions to knowledge arising from this study are summarized below:

- **A comprehensive baseline for the conservation and sustainable use of intertidal mudflats and saltmarshes in the UK has been established.** The study conducted the first known review of the UK progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes. As such, it presents a significant contribution to knowledge, both in terms of documenting history and providing a baseline against which future progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes in the UK can be assessed.

- **The concept of a systems meta-paradigm has been introduced and a framework for environmental decision-making has been suggested.** The study identified potential avenues for further development in multi-methodology systems intervention, both theoretically and in practice. It introduced, for the first known time, the concept of a systems meta-paradigm, and suggested an iterative framework for structuring and organizing intervention and change in complex problem situations that is not known to have featured previously in the debate concerning multi-methodology systems intervention.

- **A validated timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes has been constructed.** The constructed timeline synthesizes the knowledge and experiences of key stakeholders involved in the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent, UK. It presents, for the first known time, a concise record and overview of the events that are considered to have been significant in shaping current understandings and practices.

- **A better understanding of decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes has been generated.** Prior to this study, there was a significant lack of understanding about the system (or process) by which stakeholders make decisions and take actions to conserve and sustainably use intertidal mudflats and saltmarshes. This study revealed new insights (or understandings) about the decision-making process, leading to the identification of ways in which it can be improved.

- **A conceptual model for an improved decision-making process has been developed and evaluated.** The conceptual model brings together new understandings in a way that emphasizes the need for decision-making in complex problem situations to be an iterative process of social learning, in which many different types of knowledge and experiences are taken into account. The study demonstrates how it can be meaningfully applied in the context of decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes, and suggests other current and future problem situations in which it may also be applied.

These contributions to knowledge will be of particular interest to those currently or potentially involved in or affected by the conservation and sustainable use of intertidal mudflats and saltmarshes, both in the UK and elsewhere. They will also be more generally useful to those engaged in the fields of environmental governance and systems thinking in practice, including researchers and practitioners, central government bodies, local planning authorities, NGOs, consultants, commercial and industrial enterprises, and the general public. By implementing the concepts, methods and techniques developed in this study, these people can begin to make progress towards understanding and improving their particular problem situations. In this context, it is importance to emphasize that the problem situation described in section 1.3 has not gone away; and if anything, the need to understand and to improve decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes has become even more urgent.

7.4 Research limitations

The findings from this research apply to a specific group of stakeholders who were — during the course of the study — involved in or affected by decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent, UK. Notwithstanding that a number of suggestions have been made about how the findings from the study might apply more generally (which are elaborated on in section 7.5), it is recognized that claims cannot be made regarding the applicability of the research beyond its empirical domain. The empirical findings, however, give strength to the assertion made in chapter 2 that 'alongside further science-based research, the challenge is to develop a decision-making process capable of accommodating complexity, uncertainty and multiple diverse perspectives, through which more informed, timely decisions and more effective, concerted actions to conserve and sustainably use intertidal mudflats and saltmarshes can be taken'. As discussed in section 7.6, the challenge still remains, though this study has made it one small but significant step closer to being achieved. The empirical findings also support the assertions made previously by other researchers and practitioners (presented in chapter 3) that multi-methodology systems intervention is both desirable and feasible despite the potential philosophical, cultural, psychological and practical problems that it may give rise to theoretically and in practice. Further consideration is given to this subject in section 7.5.

With hindsight, it would have been useful to have been able to incorporate ways of further refining and validating the conceptual model for the 'improved' decision-making process during the course of the research. Iterative workshops in the Solent would have been one possible way of doing this. Alternatively, workshops could perhaps also have been undertaken in the same research context but in different locations in the UK and/or in a different context entirely (such as the problem situations discussed in section 7.5). In any case, additional funding would have been required to extend the research scope and duration (additional funding was not available).

7.5 Revisiting areas of application

7.5.1 Existing areas of application

The use of multi-methodology systems intervention in practice has been diverse in both context and content. As discussed in section 3.5, published papers reporting case studies demonstrate that MMSI has been used in the context of general organization, information systems, technology, resources, planning, health services and environmental management. Previous literature reviews and a range of recent case studies highlight the predominance of soft systems methodology used in combination with other methodologies and techniques. The case studies also illustrate the range of different ways in which methodologies have been combined: whether more than one methodology is used or not; whether the methodologies used come from the same or from different paradigms; whether whole methodologies are used or parts are taken out and combined; and, in the latter case, whether a single methodology is given overall control or whether the parts are linked to form a new, *ad hoc* multi-methodology. In practice, partitioning and combining methodologies, which is the most complex form of multi-methodology, appears to be less frequently applied than other ways of combining methodologies.

This study partitioned and combined methodologies in an environmental context, using a framework for environmental decision-making developed by the Open University (2006a). There are no known published papers reporting case studies which employ the framework for environmental decision-making in practice, so comparisons can not be made between this study and others in this context. However, broad comparisons can be made with studies which have used MMSI in an environmental context, albeit using different combinations of methodologies and techniques (e.g. Adamides *et al.*, 2009; Luckett *et al.*, 2001, and with studies which have partitioned and combined methodologies in non-environmental contexts (e.g. Franco and Lord, 2011; Petkov *et al.*, 2007).

Luckett *et al.* (2001) describe the first phase of an ongoing participatory action research intervention that seeks to improve the management system of a rural community-based organization in the KwaZulu-Natal province of South Africa. In the study, critical systems thinking informed the choice of systems methodologies: soft systems methodology, viable system model, concept mapping and delphi. The study concludes that the soft systems methodology process, in particular, enabled some important issues to be surfaced and some valuable lessons to be learned. They note that 'rich pictures' were useful for surfacing some important and previously unarticulated issues. Also, that the collaborative construction of a root definition was both a point of learning for the workshop participants and an insightful exercise, even though the root definition 'may have been a little simplistic'. They believe that it is only by participating in this activity that the decisions around owners, actors, beneficiaries, transformation, environment, and in particular, the 'worldview' assumptions come clearly into focus for all participants. These findings are consistent with the observations made in the pilot study phase of this research, particularly regarding the use of root definitions (chapter 6).

Adamides *et al.* (2009) combined soft systems methodology, system dynamics and multi-objective optimization in an action research project for the development of a solid waste management system for the Achaia region in Greece. They observed a willingness from low-ranking officers of local and regional authorities, and some other team members (geologists and environmental engineers), to actively contribute to tasks in the workshop, even in highly technical activities such as modelling. However, they also observed that policy-makers at higher ranks were solely interested in deliverables in the form of 'concrete' and 'objective' proposals, without any particular interest in the means of deriving them; and that their short-termism prevailed in their decisions. These finding are not consistent with the present study, in which all of the participants appeared to fully engage with each of the tasks throughout the workshop, leading to new insights and shared understandings about the problem situation, and the identification of concerted actions to improve it.

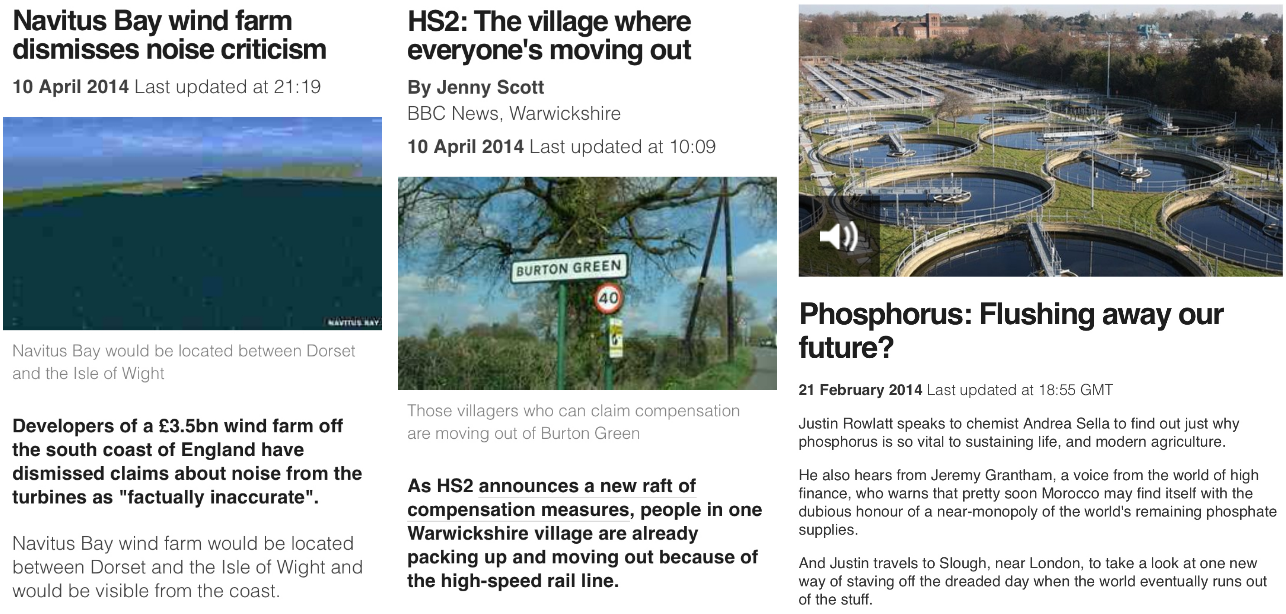
Franco and Lord (2011) report on the design and implementation of a multi-methodology systems intervention intended to support a budget prioritization decision by a multi-organizational group tasked with tackling the problem of teenage pregnancy in an English borough. The intervention involved the combined use of causal mapping and a multi-criteria decision analysis to develop and prioritize a number of projects aimed at alleviating issues associated with teenage pregnancy. They observed that participants expressed the unanimous view that the intervention helped them think in a different way about teenage pregnancy issues. In relation to the mapping workshop, participants stated that they were forced to think 'laterally' and analyse issues in more breadth and depth than would have been normally the case within strategy meetings. Furthermore, that it allowed them to re-examine the ongoing strategy. Participants also stated that the multi-criteria decision analysis changed their thinking about how they commonly did things. However, the researchers question that extent to which the intervention was successful because the final recommendations from the intervention were not fully implemented. They state that they would like to further investigate which particular combinations of methodologies are more likely to lead to the full implementation of the intervention's recommendations. Despite the suggestions that multi-criteria decision analysis was not as useful as alternative methods and techniques in the present study, it was recognized that it created space for the participants to (re-)evaluate and articulate their value positions, and to compare different options and the values expresses by other participants in a transparent way; so in this respect, the findings are broadly consistent between these studies. There are also similarities between the studies in terms of implementing recommendations, as some of the recommendations from this study remain a 'work in progress'.

Petkov *et al.* (2007) report on their experiences of combining multi-criteria decision-making and techniques from soft systems methodologies, based on their involvement in three projects within the Information and Communications Technology sector. They conclude that the combined use of the various methodologies and techniques helped the stakeholders to address the issues in the three cases, and that as a result of the interventions, the stakeholders could focus on building a common appreciation about the most important issues. Furthermore, that outcomes were used to inform management decisions related to the particular cases. They note that the methodologies and techniques that were applied in each case were seen by the stakeholders as promoting learning and participation in decision-making about their respective problem situations. In contrast, the finding from this study suggest that multi-criteria decision-making was less useful than some of the alternative methodologies and techniques used in the pilot study workshop. However, the partitioning and combining of different methodologies and techniques was, on the whole, perceived to be appropriate in the context of the pilot study workshop by both the researcher and the workshop participants; in this respect, there is general agreement between the studies.

In summary, the findings of this research are consistent with, and add strength to, assertions that multi-methodology is both feasible and desirable in practice; and in particular, that partitioning and combining methodologies in an environmental context is feasible and desirable. However, it is also apparent that some methodologies and techniques are more suitable in some problem situations than in others (and this should be expected). There is a clear need for further research in this context, and some recommendations are made in section 7.6.

7.5.2 Potential future areas of application

The research put forward a number of areas in which the general concepts and methods developed in the study could be meaningfully applied. The opportunity is taken here to demonstrate some of the potential areas of application using three recent examples from the news media (Figure 7.1). It is hoped that these examples will help to enable others to see beyond the boundary of this study, to its applicability in their own problem situations both now and in the future.


Navitus Bay wind farm dismisses noise criticism

10 April 2014 Last updated at 21:19

Navitus Bay would be located between Dorset and the Isle of Wight

Developers of a £3.5bn wind farm off the south coast of England have dismissed claims about noise from the turbines as "factually inaccurate".

Navitus Bay wind farm would be located between Dorset and the Isle of Wight and would be visible from the coast.

HS2: The village where everyone's moving out

By Jenny Scott
BBC News, Warwickshire

10 April 2014 Last updated at 10:09

Those villagers who can claim compensation are moving out of Burton Green

As HS2 announces a new raft of compensation measures, people in one Warwickshire village are already packing up and moving out because of the high-speed rail line.

Phosphorus: Flushing away our future?

21 February 2014 Last updated at 18:55 GMT

Justin Rowlatt speaks to chemist Andrea Sella to find out just why phosphorus is so vital to sustaining life, and modern agriculture.

He also hears from Jeremy Grantham, a voice from the world of high finance, who warns that pretty soon Morocco may find itself with the dubious honour of a near-monopoly of the world's remaining phosphate supplies.

And Justin travels to Slough, near London, to take a look at one new way of staving off the dreaded day when the world eventually runs out of the stuff.

Figure 7.1 Extracts from the BBC News describing stories arising from complex situations

In 2010, The Crown Estate awarded Eneco Wind UK Ltd (now in joint venture with EDF Energy) exclusive rights to develop an offshore wind farm between Dorset and the Isle of Wight. Plans for the Navitus Bay Wind Park, comprising 194 turbines up to 200 m tall, were recently submitted to the Planning Inspectorate (Navitus Bay Development Limited, 2014). According to the developers, the multi-million pound project will bring a range of benefits both nationally and locally, including enough renewable energy to power up to 710,000 homes each year and the offsetting of approximately 1,290,000 tonnes of CO_2 emissions each year, as well as a minimum of 1,700 local jobs during the four year construction phase and 140 local permanent jobs annually for the 25 year operational life of the project, and significant opportunities for local businesses to become part of the project's supply chain by providing their services and products (Navitus Bay Development Limited, 2014). However, the plans have been fiercely contested throughout the consultation process by the Challenge Navitus campaign group, who argue that the wind farm would be: embedded in a valuable national asset with an economy supported by its natural beauty and the sea; overlooked by two Areas of Outstanding Natural Beauty and a National Park; close to England's only natural World Heritage Site; closer than government recommendations for coasts of high sensitivity; closer than similar developments in Europe; in the mouth of a bay, overlooked by hills and cliffs; on an important international bird migration route; in an area of high shipping and boating activity; surrounded by coastal ecology sensitive to micro-climate change; close to sea-bird colonies and in an area currently frequented by marine mammals; and connected to the National Grid via a 22 mile underground cable route from the shore to a new substation further inland (Challenge Navitus, 2014). Although the campaigns lead to some changes in the plans submitted, the situation remains problematic for many people, not least for those who are ultimately responsible for deciding whether or not to permit the development to go ahead.

High Speed 2 (HS2) is a controversial plan by the UK Government to construct a new high-speed rail network linking London, Birmingham, Leeds and Manchester (HS2 Action Alliance, 2014). In 2009, as High Speed 1 (HS1, officially known as the Channel Tunnel Rail Link) neared completion, High Speed 2 Limited was established by the Government to develop and promote HS2 (HS2 Ltd, 2014a). With an estimated track length of 330 miles and a cost of over £50 bn, the project is unique in terms of size and scale. It is arguably the most expensive single project ever attempted by a UK government in peacetime, dwarfing projects such as the current aircraft carrier program (£7 bn plus aircraft), NHS Connecting for Health IT Program (£12 bn), Nimrod MRA4 program (£4 bn) and the Millennium Dome (£1 bn) (HS2 Action Alliance, 2014). According to HS2 Limited, Britain — like many other countries — is investing in high speed rail to create space on overcrowded networks and enable large numbers of people to move efficiently. Furthermore, they claim that the wider benefits of HS2 are also substantial, whether in economic terms, improved connections, an exciting and efficient travel experience or more comfortable, reliable local rail services (HS2 Ltd, 2014b). However, the proposals have been actively opposed since they were first announced in 2010. HS2 Action Alliance, in coalition with a number of other campaign groups, argue that the returns for this unprecedented level of expenditure are meagre: few jobs, more economic activity in London at the expense of the rest of the country, and irreversible environmental damage (HS2 Action Alliance, 2014). As with Navitus Bay Wind Park, the campaigns have lead to some perceived improvements in the plan, but these appear to have been insufficient to alleviate the concerns of many campaigners.

Phosphorus is fundamental to the existence of all living things. About 90% of the global demand for phosphorus is for food production, and mainly for agricultural fertilizers (European Fertilizer Manufacturers Association, 2000; Smil, 2000a,b). Historically, locally available organic matter such as manure and human excrement was spread over fields to replenish soil phosphate levels (Marald, 1998 cited in Cordell *et al.*, 2009). In the 20th century, to keep up with increased demand for food due to rapid population growth, guano and later rock phosphate were applied extensively to food crops (Smil, 2000b). Phosphate rock was seen as an unlimited resource and the market for mineral fertilizers developed rapidly (Cordell *et al.*, 2009). The demand for phosphorus is predicted to increase by 50–100% by 2050 with increased global demand for food and changing diets. However, studies estimate that commercially viable phosphate rock reserves will be depleted in 60–130 years (European Fertilizer Manufacturers Association, 2000; Steen, 1998). Phosphate rock reserves are concentrated mainly in Morocco, China and US, and thus are subject to international political influences. Morocco has a near monopoly on Western Sahara's reserves, China is reducing exports to secure domestic supply and US has less than 30 years left of supplies, while Western Europe and India are totally dependent on imports (Jasinski, 2006; Rosmarin, 2004). In 2008, the demand for phosphate rock and fertilizer exceed production capacity of mines and fertilizer plants. Prices increased by 700% in a 14-month period (von Horn and Sartorius, 2009). In India, there have been instances of farmer riots and deaths due to the severe national shortage of fertilizers (Farming UK, 2008). In addition to the sustainability issue, the use of phosphorus is also problematic is other ways. Phosphorus from agricultural run-off, combined with point source discharges into waterways from waste water treatment works, have contributed to eutrophication. The production of fertilizers from rock phosphate also involves significant carbon emissions, radioactive by-products and heavy metal pollutants, and processing and transporting phosphate fertilizers from the mine to the farm, which relies on cheap fossil fuels, involves an ever-increasing energy cost (Cordell *et al.*, 2009). The news story offers some hope for the future, reporting on Europe's first phosphorus recovery facility at Slough Water Treatment Works in the UK, which converts phosphorus from sewage into agricultural fertilizer pellets. But, it also brings into sharp relief the food-water-energy security nexus.

Each of these three stories arise from complex problem situations. The problem of Navitus Bay Wind Park is not confined within its geographical boundary, but extends locally, nationally and globally; from the displacement of marine habitats and species, to impacts on coastal and marine industries, to national energy policies, to global agreements on biodiversity and climate change. Similarly, HS2 is not just a problem of infrastructure design;

there are many interrelated factors involved, and contrasting perspectives on the situation that range from individuals wanting to travel easily and safely, to local communities worrying about the impacts of the new rail network on livelihoods, to politicians striving for national economic growth and sustainable development. For Slough Water Treatment Works, the 'localized' problem of phosphorus in sewage has much wider causes and consequences; the invention of flushing toilets, population growth and increasing food demand, EU policies and their unintended environmental and social impacts elsewhere. From the researcher's perspective, the concepts and methods developed in this study offer one possible way towards continuous improvement in these three situations, and potentially many other complex and 'messy' problem situations calling for better human intervention.

7.6 Recommendations for further research

Based on the findings from this study, three potential areas for further research are recommended:

1. a review of global progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes;
2. the application of the concepts and methods developed in this study in other contexts; and
3. an investigation into enabling new and different ways of thinking and acting (such as the decision-making process developed in this research) on a local, national and global scale.

The study reviewed the UK progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes; but in doing so, it also raised questions about progress that is being made elsewhere. A more comprehensive, global review is timely given the significant losses of intertidal mudflats and saltmarshes that have been reported in many other countries.

The concepts and methods developed and evaluated in the study are transferable to other coastal regions where the conservation and sustainable use of intertidal mudflats and saltmarshes is problematic; and also to other complex, problematic decision-making situations in the UK and elsewhere. Future studies could therefore help to further refine and justify the use of these concepts and methods by applying them in a range of different situations.

The study has made significant progress towards understanding and improving decision-making for the conservation and sustainable use of intertidal mudflats and saltmarshes. But, further work is required before the improvements can be implemented on a local, national or global scale. Future research could investigate the barriers and opportunities for multi-methodology systems intervention in mainstream decision-making practice.

Part V

Appendices

Appendix A

Intertidal mudflat and saltmarsh services

Table A.1, Table A.2, Table A.3 and Table A.4 present an analysis of intertidal mudflat and saltmarsh services classified according to the Millennium Ecosystem Assessment (2005b). Provisioning services are the products obtained from mudflats and saltmarshes. Regulating services are the benefits obtained from the regulation of mudflat and saltmarsh processes. Cultural services are the non-material benefits people obtain through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences associated with mudflats and saltmarshes. Supporting services are those that are necessary for the production of all other mudflat and saltmarsh services.

Table A.1 Provisioning services

Services	Comments and examples
Food	Historically, mudflats and saltmarshes have been exploited for agricultural and horticultural purposes, with the earliest uses being grazing, samphire gathering and hay-making (Doody, 1992). They also provide feeding grounds for a range of internationally important overwintering and migratory birds, particularly waders and wildfowl. The latter, in turn, may become a food source for the 'wildfowler' (Doody, 1992; McMullon, 2008). Likewise, they are an important nursery ground for fish and other marine species, which provide food for humans and other animals (UK Biodiversity Group, 1999). Capture fisheries in coastal waters alone account for US $34 billion in yields annually (Millennium Ecosystem Assessment, 2005b).
Fresh water	Mudflats and saltmarshes are not directly associated with the provision of fresh water as a result of their physical location and frequent inundation by seawater, but they contribute indirectly via their regulating services, as described below.
Fibre and fuel	Large expanses of mudflats and saltmarshes have been reclaimed to provide land for industrial developments, such as petrochemical complexes and ports, upon which humans depend for materials and fuel (Allen and Pye, 1992; Doody, 1992). This is particularly apparent, for example, in Teesmouth (County Durham, UK), where over 2000 hectares had been developed by 1974 for port facilities. Likewise, in Southampton Water (Hampshire, UK), where about 1090 hectares have been reclaimed for docks and other developments (Doody, 1992). Shipping contributes £37 billion to the UK economy, and 95% of goods arrive by sea HCMM (2008).
Biochemical products	Saltmarsh plants provide medicines for human use. For example, the leaves from the saltmarsh herb *Suaeda monoica* is known to be traditionally used as a medicine for hepatitis and, scientifically, it is reported to be used as ointment for wounds and possess antiviral activity (Ravikumar *et al.*, 2010).
Genetic materials	Saltmarshes are a habitat for a range of plant species that grow nowhere else, e.g. small cordgrass (*Spartina maritima*), which is restricted uniquely to saltmarshes and is known to exist in only a few locations in the UK, such as Newtown Harbour on the Isle of Wight (McMullon, 2008).

Table A.2 Supporting services

Services	Comments and examples
Biodiversity	Mudflats and saltmarshes provide habitat for resident and transient species, including internationally important bird species and stocks of plants adapted to grow on saline soils worth protecting for their intrinsic value (McMullon, 2008). There is increasing recognition of the biodiversity value of these habitats that is reflected by their designation in many locations across the UK as special areas of conservation and/or special areas for protection by the Habitats Directive and Birds Directive respectively.
Soil formation	Mudflats and saltmarshes contribute to soil formation through the accumulation of fine sediments and organic biomass, as described in Table A.4.
Nutrient cycling	Mudflats and saltmarshes act as both a nutrient sink and source, through the accumulation of minerals in soil, and the provision of minerals that plants take from the soil and air, which are returned again when they, or their consumers, die.

Table A.3 Cultural services

Services	Comments and examples
Spiritual and inspirational	Relative to other habitats in Britain (e.g. woodlands and beaches), saltmarshes have received little attention or general appreciation (Long, 1981). But, from some people, they are a source of inspiration. For example, in The Snow Goose, Gallico (1941, p. 1) writes: 'one of the last wild places of England, a low, far-reaching expanse of grass and half-submerged meadowlands ending in the great saltings and mudflats and tidal pools near the restless sea [...] It is desolate, utterly lonely, and made lonelier by the calls and cries of the wildfowl that made their homes in the marshlands'.
Recreational	Saltmarshes provide a backdrop for recreational activities, particularly walking and bird-watching (Boorman, 2003). Furthermore, the demand by tourists for biologically rich sites to visit increases the value of intrinsically linked sites such as saltmarshes, mudflats and their associated eelgrass beds (Millennium Ecosystem Assessment, 2005b).
Aesthetic	Wetlands are important tourist destinations because of their aesthetic value and the high diversity of plant and animal life they contain (Millennium Ecosystem Assessment, 2005b). In south-east England, tourism is one of the largest industries, generating over £13 billion per annum in terms of visitor expenditure and providing jobs for over 300,000 people (Tourism South East, 2011).
Educational	Saltmarshes and, to a lesser extent, mudflats have long been studied. Academics, such as geomorphologists, sedimentologists and geochemists, value saltmarshes as dynamic natural environments in which the interaction of natural physical, chemical and biological processes can be observed, monitored and demonstrated for teaching purposes (Allen and Pye, 1992).

Table A.4 Regulating services

Services	Comments and examples
Climate regulation	Wetlands, including mudflats and saltmarshes, play two critical but contrasting roles in climate change: the regulation of greenhouse gases, especially carbon dioxide (e.g. by photosynthesis); and the physical buffering of climate change impacts, as described below (Millennium Ecosystem Assessment, 2005b). Both of these roles may become significantly more important in the future to mitigate the increasing effects of climate change.
Hydrological regimes	Mudflats and saltmarshes can either increase or decrease particular components of the water cycle. They are influenced by the inflow of fresh water from catchments as well as by the tides and other coastal/oceanic factors that, in turn, influence fresh water aspects of the water cycle, e.g. via evapotranspiration rates (Millennium Ecosystem Assessment, 2005b).
Pollution control and detoxification	Water flowing through a wetland area, such as a mudflat-saltmarsh system, may be considerably cleaner upon its exit from the wetland. For example, metals and many other organic compounds may be adsorbed to the sediments. Also, the relatively slow passage of water through mudflat-saltmarsh systems provides time for pathogens, such as from sewage effluents, to lose their viability or be consumed by other organisms in the system (Millennium Ecosystem Assessment, 2005b). In some places, saltmarshes have been reclaimed from the sea and used for the land-filling of wastes, e.g. at Lymington (Hampshire, UK) (Doody, 1992).
Erosion protection	Mudflat-saltmarsh systems may be a natural and sustainable form of coastal erosion protection. Colonization of mudflat by mats of filamentous algae and/or biological 'glues', known as extracellular polymeric substances, from various types of algae bind deposited sediment particles together. This stabilizes the sediments and helps to retain them within the system, particularly if such stabilization reduces the requirement for dredging of shipping navigation channels, which frequently results in the loss if sediment from the system as a result of offshore dumping. Likewise, saltmarsh plant roots also bind the sediment, while the plant stems retard the water flow and trap the mud, encouraging deposition (Open University, 1999; Ranwell, 1981).
Natural hazards	Mudflats and saltmarshes absorb wave and tidal energy before it reaches the shore. The attenuation helps to protect hard defence structures, such as sea walls, to landward of the saltmarsh from damage by the sea and also may significantly reduce the extent of hard defence structures required, which in turn, reduces the economic cost of building and maintaining such structures (Environment Agency, 2007a). This is likely to become more important in the future as the effects of climate change, such as sea level rise and increased storminess, are manifested.

Appendix B

UK and international intertidal mudflat and saltmarsh reparation examples

Table B.1 and Table B.2 present the UK experience of IMSR via managed realignment and beneficial use of dredged materials respectively, with the caveat that there may be errors or omissions. Table B.3 presents examples of international projects.

Table B.1 UK managed realignment projects (ABPmer, 2010)

Location	Year	Area (ha)
Northey Island, Blackwater estuary, Essex	1991	0.8
Seal Sands (north-west enclosure), Tees	1993	9.0
Pawlett Hams, Parret	1994	4.8
Tollesbury, Blackwater estuary	1995	21.0
Saltram (Blaxton Meadow), Plym	1995	4.2
Ryan's Field, Hayle	1995	6.2
Orplands, Blackwater estuary	1995	38.0
Horsey Island, Hamford Water	1995	1.2
Abbotts Hall, Blackwater estuary	1996	20
	2002	84
Thornham Point, Chichester Harbour	1997	6.9
Montrose Basin, Mains of Dun	1997	0.3
Millennium Terraces, Thames	1998	0.5
Lantern Marsh (north), Ore	1999	29.0
Watertown Farm, Yeo	2000	1.5
Trimley Marsh, Orwell	2000	16.5
Havergate Island, Ore	2000	8.1
Chalkdock Marsh, Chichester Harbour	2000	3.3
Annery Kiln, Torridge	2000	3.8
Black Devon Wetlands, Forth/Black	2000	7.0
	2005	21.0
Pillmouth (Phase 1 and 2), Torridge	2000/01	12.9
Cone Pill, Severn estuary	2001	c.50.0
Bleadon Levels, Axe	2001	13.0
Freiston, The Wash	2002	66.0
Brandy Hole, Crouch	2002	12.0
Brancaster West Marsh, North Norfolk	2002	7.5
Glasson, Conder	2002	6.4
Paull Holme Strays, Humber	2003	80.0
Nigg Bay, Cromarty Firth	2003	25.0
Walborough, Axe	2004	4.5
Thorness Bay, The Solent	2004	7.0
Goosemoor, Clyst	2004	6.3
Mansands, South Devon coast	2004/07	2.0
Halvergate (Five Mile Reach and Seven Mile House), Yare	2005	c.5.0
Welwick, Humber	2006	54.0
Wallasea, Crouch	2006	115.0
Vange Marsh, Thames	2006	1.0
Lepe, Dark Water	2006	c.5.0
Chowder Ness, Humber	2006	15.0
Barking Creek — Barking Barrier, Thames	2006	1.0
Barking Creek — A13, Thames	2006	<0.1
Alkborough, Humber	2006	370.0
Treraven Meadows, Camel	2007	14.0
Hesketh Out Marsh, Ribble estuary	2008	180.0
Alnmouth, Aln	2008	20.0
	2006	8
Warkworth, Coquet	2009	0.4
Black Hole Marsh, Axe	2009	6.0
London Gateway Wildlife Reserve (Standford le Hope), Thames	2010	27.0
Goswick Farm (Beal), South Low River	2010	4.5
Devereux Farm, Hamford Water	2010	15.0
Medmerry, The Solent	2013	183

Table B.2 UK beneficial use of dredged materials projects

Location	Year	Size (m^3)	Remarks
Horsey Island (north-east), Hamford Water	1990	<180,000	First known beneficial use project in the UK. Thames barges were placed in 1988 in an effort to dissipate wave energy. In 1990, using material from the Harwich Approaches capital dredge — part of a series of measures to mitigate the impact of the channel deepening — this was followed by recharging with sands and gravels between the barges. Dredged material was 'rainbowed' onto the mid-intertidal area at high water in spring tides (Environment Agency, 2007a)
	1998		Silts from Harwich harbour discharged into the area between the sand barrier and the sea wall (Thompson *et al.*, 2011)
	2005		Silts from Harwich harbour discharged into the area between the sand barrier and the sea wall (Thompson *et al.*, 2011)
Horsey Island (south-east), Hamford Water	1992	c. 1,000	Silt from Harwich Harbour deposited on a 0.5 ha plot of heavily grazed saltmarsh (Environment Agency, 2007a)
	1997	20,000	Mud from Harwich Haven Authority's port development deposited between a shingle berm and the sea wall during the late summer so that the sediment had time to consolidate before the main release period for the seeds of saltmarsh plant species. Material was 'rainbowed' on the marsh using a fixed distributing nozzle (Environment Agency, 2007a)
	2001		The same area was recharged to facilitate the establishment of higher saltmarsh plants (Environment Agency, 2007a)
	2005		Further recharge during 2005 (Environment Agency, 2007a)
Peewit Island, Blackwater estuary	1992	2529	(DEFRA, 2004)
	1995	2646	(DEFRA, 2004)
Parkeston Marshes, Stour estuary, Suffolk	1993/94	250,000	Dredged materials 'rainbowed' onto intertidal mudflats (Environment Agency, 2010a)
Maldon, Blackwater estuary	1993		Saltmarsh stabilization by direct placement of dredged material(Nottage and Robertson, 2005)
	2001	3000 tonnes	Further recharge (Nottage and Robertson, 2005)
Parkestone Bay, Poole Harbour	1994/95		Intertidal mudflat creation during winter to provide compensation for the loss of an area of foreshore that was removed as part of the redevelopment of a yacht club's facilities (DEFRA, 2004; Nottage and Robertson, 2005)
The Horse, Stour estuary	1996		Trickle charging of sediment by pipeline (Fletcher *et al.*, 2002)
Medway estuary	1996	4,000	Silt from Medway port used for trickle charge (UK marine SACs project, 2011b)
Shotley (north), Orwell estuary	1997	22,000	A trial recharge scheme undertaken by the Harwich Haven Authority and the Environment Agency. Gravel and clay bunds back-filled with maintenance dredgings comprising mostly silt. The placement extended over 450 m of the foreshore with a maximum width of 70 m (Environment Agency, 2007a)
	2004		Areas of existing gravel topped up with silts and another scheme constructed based on bunds created using in-situ material backfilled with 0.3 m of silts (Environment Agency, 2007a)
Foulton Hall, Hamford Water	1998		Received sand and gravel recharge material from the Harwich Approaches deep channel dredge (Thompson *et al.*, 2011)
Old Hall Point, Hamford Water	1998		Received sand and gravel recharge material from the Harwich Approaches deep channel dredge, which has been effective in protecting the point.(Atkinson *et al.*, 2001; Colenutt, 2001; Thompson *et al.*, 2011)

Continued...

Table B.2 UK beneficial use of dredged materials projects continued

Location	Year	Size (m^3)	Remarks
Cobmarsh Island, Blackwater estuary	1998		Coarse material of sands and gravels, sourced from the Harwich ports capital dredge, was placed at the south-eastern tip of Cobmarsh. This has acted as a wave break in this exposed area. (Atkinson *et al.*, 2001; Thompson *et al.*, 2011)
Tollesbury Wick, Blackwater estuary	1998		Recharge material of sands and gravels, arising from the deepening of the Harwich Approaches channel, was placed at Shingle Head Point and may have helped to stabilise the point sufficiently to support vegetation growth. (Atkinson *et al.*, 2001; Thompson *et al.*, 2011)
Wallasea Ness, River Crouch	1998		Coarse grade materials (Atkinson *et al.*, 2001)
Trimley marsh, Orwell estuary	1998	c. 22,000	(Atkinson *et al.*, 2001; UK marine SACs project, 2011a)
	2001	35,000	Site extended via managed realignment. Dredged materials pumped via floating pipeline through the breach to a floating pontoon, then pumped onto the site (Atkinson *et al.*, 2001; Environment Agency, 2007a)
	2004	102,000	Gravel was dredged from the new approaches and placed onto the foreshore to construct bunds (comprising c. 22,000 m^3 of gravel) and an island for nesting little terns (comprising c. 80,000 m^3 of gravel) (Environment Agency, 2007a)
Titchmarsh marina, Hamford Water	1998	c. 10,000 tonnes	Mud from marina dredgings pumped into a bunded area (CEFAS, 2010).
	1999	c. 10,000 tonnes	Further recharge of the bunded area using marina dredgings (CEFAS, 2010)
	2001		Further recharge to raise the bed level for saltmarsh plant development. 60–80 cm vertical overburden of fine-grained dredged materials placed in saltmarsh channels (Bolam and Whomersley, 2005; CEFAS, 2010; Widdows *et al.*, 2006)
	2007		Further recharge using marina dregdings (Thompson *et al.*, 2011)
Westwick marina, River Crouch	2001		60–80 cm vertical overburden of fine-grained dredged materials placed in saltmarsh channels (Bolam and Whomersley, 2005; Widdows *et al.*, 2006)
Hythe to Cadland, Southampton Water	2001	c. 1,000	Mud 'trickle charged' onto the foreshore from bottom-dumping barges at high water. Trial site as part of Dibden dock expansion proposal (Hurley, 2003). Development refused planning permission on the basis that 'in accordance with the relevant conservation legislation, the project can only be allowed to proceed for imperative reasons of overriding public interest' and 'the Dibden Terminal would not serve a public interest that is of such importance as to outweigh the adverse impacts of the proposed development' (Butcher, 2010)
Suffolk Yacht Harbour, Orwell estuary	Since at least 2003	20,000 annually	Dredged materials pumped via pipeline to raise intertidal mud levels adjacent to the harbour (CEFAS, 2010; Royal Haskoning, 2003)
Shotley (south), Orwell estuary	2004		Construction of clay bunds around Shotley Marina backfilled with silt
Wallasea Island, River Crouch	2006	c. 500,000	Dredged materials used to raise the bed level prior to managed realignment (Dearnley *et al.*, 2007)
Cindery Island, Colne estuary	2010/12		Brightlingsea Harbour Authority are using silts dredged from the harbour to recreate saltmarsh, discharging into disused oyster pits (Marine Management Organisation, 2010; Thompson *et al.*, 2011)
Lymington Marina, Lymington	2012		Intertidal recharge to mitigate for the impacts of a new breakwater on a designated saltmarsh conservation area (The Crown Estate, 2012; Willowbank Services, 2012)
Boiler marsh, Lymington	2012	c. 2000	Intertidal recharge to mitigate for the operational impacts of new ferries (ERM, 2010a)

Table B.3 International mudflat and saltmarsh reparation examples

Location	Year	Area (ha)	Remarks
Faber Tract, San Francisco Bay, California, USA	1972	32	Dredged material site (Williams and Faber, 2001)
Pond 3, San Francisco Bay, California, USA	1975	44	Trickle charge and bioengineering (planting) (Colenutt, 2001; Williams and Faber, 2001)
Muzzi, San Francisco Bay, California, USA	1976	52	Trickle charge. Breaching of existing dike (Colenutt, 2001; Williams and Faber, 2001)
Bair Island, San Francisco Bay, California, USA	1978	60	Managed realignment site (Williams and Faber, 2001)
Cogswell, San Francisco Bay, California, USA	1980	80	Managed realignment site (Williams and Faber, 2001)
Warm Springs, San Francisco Bay, California, USA	1986	80	Managed realignment site (Williams and Faber, 2001)
Strandseenlandschaft near Schmoel, Kiel Bay, Schleswig-Holstein, Germany	1989	40–50	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Wrauster Bogen, Riepenburg, Spadenlander Spitze, Kreetsand, Elbe Estuary, Hamburg, Germany	1990s	35–37	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Karrendorfer Wiesen, Greifswald Bodden, Mecklenburg-western Pomerania, Germany	1993	350	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Carls Marsh, San Francisco Bay, California, USA	1994	22	Managed realignment site (Williams and Faber, 2001)
Hauener Hooge polder, Ley Bay, Lower Saxony, Germany	1994	80	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Riedensee Nature Reserve, Mecklenburg Bay, Mecklenburg-western Pomerania, Germany	1995/99	10	Initial accidental breach, followed by management measures (Rupp-Armstrong and Nicholls, 2007)
Polder Friedrichshagen(Ziesetal), Greifswald Bodden, Mecklenburg-western Pomerania, Germany	1995/99	190	Initial accidental breach, followed by management measures (Rupp-Armstrong and Nicholls, 2007)
Pond 2A, San Francisco Bay, California, USA	1995	220	Managed realignment site (Williams and Faber, 2001)
Sonoma Baylands, San Francisco Bay, California, USA	1996	120	Inter-tidal recharge and bioengineering (planting) (Colenutt, 2001; Williams and Faber, 2001)
Vor-/Hinterwerder polder, Weser Estuary, Bremen, Germany	1997	22	Breach and lowering (Rupp-Armstrong and Nicholls, 2007)
Tegeler Plate polder, Weser Estuary, Lower Saxony, Germany	1997	210	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Tolay Creek, San Francisco Bay, California, USA	1999	20	Managed realignment site (Williams and Faber, 2001)
Polder Roggow, Salzhaff, Mecklenburg-western Pomerania, Germany	2000/02	40	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Polder Freetz, SE Rugen, Mecklenburg-western Pomerania, Germany	2000/01	180	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Dorum polder, Wurster Coast, Lower Saxony, Germany	2001	4	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Polder Neuensien, SE Rugen, Mecklenburg-western Pomerania, Germany	2001	80	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)

Continued...

Table B.3 International mudflat and saltmarsh reparation examples continued

Location	Year	Area (ha)	Remarks
Comacchio, Adriatic coast of the Emilia-Romagna region, Italy	2001/06	600	The salt works located in the Po Delta Regional Park at Comacchio ceased operating in 1984. A five-year LIFE-Nature project was implemented by the Emilia-Romagna regional authority to restore a 600 ha section of the salt marshes and to promote the recovery of habitats and associated water bird species (LIFE, 2007)
Kleines Noor Flensburg Fjord, Schleswig-Holstein, Stiftung Naturschutz Schleswig-Holstein (2002)	2002	18	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Pepelower/Tessmansdorfer Wiesen, Salzhaff, Mecklenburg-western Pomerania, Germany	2002	160–180	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Anklamer Stadtbruch Oderhaff, Mecklenburg-western Pomerania, Germany	2002/04	1750	Initial accidental over-topping in 1995, leading to extensive flooding (Rupp-Armstrong and Nicholls, 2007)
Island of Langeoog polder, Langeoog, Lower Saxony, Germany	2003	218	Managed realignment site (Rupp-Armstrong and Nicholls, 2007)
Poplar Island Paul S. Sarbanes ecosystem restoration project, Chesapeake Bay, Talbot County, Maryland District, USA	in progress	694	In 1994, the USACE teamed with the Maryland Port Administration and other Federal and State agencies to restore the island to its 1847 footprint using dredged material from the Baltimore Harbour and Channels Federal navigation projects. Approximately 52 million cubic metres of dredged material will be placed to develop 297 ha of wetlands, 340 ha of uplands and 57 ha of open water embayment. The estimated completion date is 2014. (USACE, 2010)
Mid-Chesapeake Bay Island Ecosystem Restoration, Dorchester County, Maryland District, USA	in progress	838	Currently in pre-construction phase, the project develops a long-term strategy for providing viable placement alternatives that meet the dredging needs of the Port of Baltimore while maximizing the use of dredged materials as a beneficial resource. The conceptual plan for the feasibility study proposes 55 % wetland and 45 % upland habitats (USACE, 2012).

Appendix C

Timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from 1800 to 2016

Figure C.1 shows a timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent. See Table C.1 for further details and references.

Table C.1 lists the events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from 1800 to 2016. Events are listed chronologically by year, then alphabetically by author.

Figure C.1 Timeline of events pertaining to the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent from 1800 to 2016. Past, present and future events are shown chronologically so far as is reasonably practicable.

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Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016

Year	Name	Event	References
1801–1805	Anon.	75 ha embanked to grow corn in Bosham Creek, Chichester Harbour	Tubbs (1999)
1803	UK Parliament	Board of Harbour Commissioners established by Act of Parliament to improve Southampton Dock facilities	Biddle (1955); Coughlan (1979)
1805–1809	Anon.	390 ha reclaimed for pasture in Sidlesham Ferry/Bracklesham Bay, Selsey Bill	Tubbs (1999)
1829	Anon.	Earliest known record and collection of *Spartina alterniflora* in the Itchen estuary	Jacquet (1949) cited in Marchant (1967)
1832	Southampton Corporation (now City Council)	Part of the area known as Salt Marsh on Itchen-Test peninsula sold for the construction of Terminus Rail Station following the formation of London and Southampton Railway Company	Coughlan (1979)
1833	London and Southampton Railway Company	Construction of Royal Pier	Coughlan (1979)
1836	Bromfield, W.	Detailed description of *Spartina alterniflora* growing in Southampton Water and the River Itchen	Bromfield (1836)
1836	Southampton Dock Company	216 ha mostly intertidal mudflats acquired for the construction of Old Docks following the establishment of Southampton Dock Company to provide facilities comparable to those available in Liverpool and London	Coughlan (1979)
1842-1912	Anon.	200 ha reclaimed for successive Dockyard expansion in Portsmouth Harbour	Tubbs (1999)
1842	Southampton Dock Company	Construction of Outer Dock completed	Coughlan (1979)
1844	Southampton Corporation	Remaining area of Salt Marsh drained	Coughlan (1979)
1844	UK Parliament	Enactment of the Southampton Marsh Improvement Act 1844	Marsh Improvement Act 1844 (7 & 8 Vict., c. liv)
1851	Southampton Dock Company	Construction of Inner Dock completed	Coughlan (1979)
1869	UK Parliament	Enactment of the Sea Birds Preservation Act 1869	Sea Birds Preservation Act 1869 (32 & 33 Vict., c. 17)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1870s	Anon.	Pagham Harbour enclosed from the sea under a Private Act of Parliament enacted in 1973	Tubbs (1999)
1870	Anon.	300 ha mudflats and saltmarshes reclaimed at Thorney Deep (between Thorney Island and mainland)	Tubbs (1999)
1870	Hill, R. S.	*Spartina townsendii* collected in Southampton Water, subsequently recognized as a species in 1879 and named in 1880 by Groves brothers	Groves and Groves (1879, 1881, 1882); Stapf (1913)
1872	UK Parliament	Enactment of the Protection of Wild Birds Act 1872	Protection of Wild Birds Act 1872 (35 & 36 Vict., c. 78)
1876	UK Parliament	Enactment of the Preservation of Wild Fowl Act 1876	Preservation of Wild Fowl Act 1876 (39 & 40 Vict., c. 29)
1878	Liberator Building Society	354 ha enclosed from the sea at Brading Harbour	Tubbs (1999)
late 1870s	Anon.	Failed attempt to embank 554 ha at Thorney Island (between the inlet and penisula)	Tubbs (1999)
1880–1908	UK Parliament	Enactment of the Wild Birds Protection Acts 1880–1908	Wild Birds Protection Act 1880 (43 & 44 Vict., c. 35), 1881 (44 & 45 Vict., c. 51), 1894 (57 & 58 Vict., c.24), 1896 (59 & 60 Vict., c. 56), 1902 (2 Edw. 7, c. 6), 1904 (4 Edw. 7, c. 4), 1908 (8 Edw. 7, c. 11)
1889	Ministry of Defence	Great and Little Horsea Islands in Portsmouth Harbour joined by reclamation to form a torpedo testing lake	Ripley (1982)
1890	Southampton Dock Company	Excavation of Empress Dock with money loaned from the renamed London and South West Railway Company (formerly London and Southampton Railway Company)	Coughlan (1979)
1892	Hubbard, C. E.	First known collection of *Spartina anglica* in Lymington, subsequently recognized as a species in 1956 and named in 1968	Hubbard (1957, 1968)
1892	London and South West Railway Company	Docks purchased from Southampton Dock Company	Coughlan (1979)
1895	Hill, O., Hunter, R. and Rawnsley, H. D.	National Trust founded	Murphy (2002)
1898	Beaulieu Estate	First known record of *Spartina* planting in the Beaulieu estuary	Hubbard and Stebbings (1967); Tubbs (1999)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1899	Rothschild, C.	Wicken Fen, Cambridgeshire becomes the first UK nature reserve, gifted to the National Trust by Rothschild	The Wildlife Trusts (2013d)
1900	Anon.	5 ha saltmarsh enclosed by the construction of a causeway and bridge across the western Yar estuary	Tubbs (1999)
1910		Sea breach of embankment in a storm at Pagham Harbour, 244 ha not subsequently reclaimed	Tubbs (1999)
1911	London and South Western Railway Company	Construction of Ocean Dock	Coughlan (1979)
1912	Rothschild, C.	Society for the Promotion of Nature Reserves founded	The Wildlife Trusts (2013c)
1913	Stapf, O.	Description of the spread of *Spartina townsendii* in the Solent	Stapf (1913)
1915	Rothschild and Society for the Promotion of Nature Reserves colleagues	Compiled a list of 284 sites considered 'worthy of preservation' across the UK including Solent sites	The Wildlife Trusts (2013b,c)
1917–1970	Anon.	80 ha reclaimed for waste disposal and M27 motorway construction in Langstone Harbour	Tubbs (1999)
1920	Atlantic Gulf West Indies Company (now ESSO)	15 ha saltmarsh reclaimed north of ESSO jetty for the construction of a small oil refinery, which was progressively enlarged	Coughlan (1979)
1923	Southern Railway	Southampton Docks transferred from London and South West Railway Company	Coughlan (1979)
1925	Oliver, F. W.	'*Spartina townsendii*: its mode of establishment, economic uses and taxonomic status'	Oliver (1925)
1925–1967	UK Parliament	Enactment of the Protection of Birds Acts 1925–1967	Protection of Birds Act 1925 (15 & 16 Geo. 5, c. 31), 1933 (23 & 24 Geo. 5, c. 52), 1954 (2 & 3 Eliz. 2, c.30) as amended, 1967 (c. 46)
1927–1933	Southern Railway	400 ha intertidal mudflats reclaimed for New (Western) Docks construction	Coughlan (1979)
1928	Anon.	*Spartina* planting in Brading Harbour	Hubbard and Stebbings (1967)
1928	Manners, J. G.	Saltmarsh degeneration first recorded in the Beaulieu estuary	Manners (1975)
1933	Anon.	*Spartina* planting in Newtown Harbour	Hubbard and Stebbings (1967)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1940–1967	Anon.	Progressive reclamation of 176 ha at Dibden Bay in Southampton Water in 1940, 1951, 1958 and 1967	Coughlan (1979)
1941	Society for the Promotion of Nature Reserves	Conference on Nature Preservation in Post-War Reconstruction	Bassett (1980)
1842-1912	Anon.	200 ha reclaimed by successive Dockyard expansion in Portsmouth Harbour	Tubbs (1999)
1942	Jowitt, W.	Nature Reserves Investigation Committee set up to examine proposals for the establishment of nature reserves as part of any general scheme of national planning	Bassett (1980)
1943	UK Government	Reclamation for the construction of Marchwood Military Port	Coughlan (1979)
1947	British Transport Docks Board	Southampton Docks nationalized	Coughlan (1979)
1947	Huxley, J. S.	Wild Life Conservation Special Committee set up under the chairmanship of Dr. J. S. Huxley to advise the newly formed National Parks Committee	UK Government (1947)
1949	UK Parliament	Enactment of the Coast Protection Act 1949	Coast Protection Act 1949 (12, 13 & 14 Geo. 6, c.74)
1949	UK Parliament	Enactment of the National Parks and Access to the Countryside Act 1949	National Parks and Access to the Countryside Act 1949 (12, 13 & 14 Geo. 6, c.97)
1949	UK Government	Nature Conservancy established under the National Parks and Access to the Countryside Act 1949	Bassett (1980)
1950	Austwick, P. K. C.	Report on investigations into the cause of dying-out of *Spartina townsendii* Groves in Lymington Harbour at the request of British Railways (then owners of the ferry between Lymington and Yarmouth), who were concerned with increased dredging requirements possibly due to mud-slip	Austwick (1950); Manners (1975)
1951–2000	Nature Conservancy, Nature Conservancy Council and English Nature (now Natural England)	22 SSSIs relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes declared in the Solent	Natural England (a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r,s,t,u,v)
1952	Anon.	8 ha mudflats reclaimed plus 5.5 ha lost due to dredging for Marchwood Power Station	Coughlan (1979); Tubbs (1999)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1953		Sea breach of coastal defences during a storm, flooding most embanked marshes across the Solent. Main Marsh in Newtown Harbour, Bunny Meads in the Hamble estuary, Exbury Marsh in the Beaulieu estuary, and several other smaller areas not subsequently reclaimed	Tubbs (1999)
1955/56		Sea breach of coastal defence during a storm at Sowley marsh, Lymington	Tubbs (1999)
1956	Drummond, M. and others	Solent Protection Society (SPS) established	Solent Protection Society (2013)
1957	Braybrooks, E.	'The general ecology of *Spartina townsendii* with special reference to sward build-up and degradation'	Braybrooks (1957)
1957	Goodman, P. J.	'An investigation of die-back of *Spartina townsendii*'	Goodman (1957)
1960s	Portsmouth City Council.	240 ha intertidal mudflats reclaimed between Horsea Island and Paulsgrove in Portsmouth Harbour for motorway construction, waste disposal and a marina	Tubbs (1999)
1960	Anon.	Hampshire and Isle of Wight Wildlife Trust established	Hamshire and Isle of Wight Wildlife Trust (2013)
1961	Anon.	Sussex Wildlife Trust established	Sussex Wildlife Trust (2013)
1962	National Power	66 ha saltmarsh reclaimed, plus 24 ha of embanked marsh, then a further 44 ha saltmarsh for Fawley Power Station	Coughlan (1979)
1964	Barker, S.	'A study of competition between *Juncus maritimus* and *Spartina townsendii*'	Barker (1964)
1964–2000	Nature Conservancy and Local Authorities	2 national nature reserves and 16 local nature reserves relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes declared in the Solent	Natural England (2013a,b,c,d,e,f,g,h,i,j,k,l,m,n,o,p,q,r)
1966	Ivemy, A.	'Studies in the physiology of water logging and anaerobiosis'	Ivemy (1966)
1968	UK Parliament	Enactment of the Countryside Act 1968	Countryside Act 1968 (c. 41)

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Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1970–1997	British Transport Docks Board	c. 109 ha of intertidal mudflats and saltmarshes reclaimed for Western Docks extension (berths 201–207) in four phases completed in 1969, 1972/73, 1976 and 1997 respectively	ABP (2010); Coughlan (1979)
1971	UK Government	Ramsar Convention adopted in 1971 and ratified in 1976	Convention on Wetlands of International Importance especially as Waterfowl Habitat
1975	Baker, J. M.	'The effects of oil pollution on *Spartina anglica*'	Baker (1975)
1975	Coughlan, J.	'Reclamation of *Spartina marshes*'	Coughlan (1975)
1975	Gessner, R. V.	'Fungi associated with *Spartina alterniflora*: seasonal succession and distribution'	Gessner (1975)
1975	Manners, J. G.	'Die-back of *Spartina* in the Solent'	Manners (1975)
1975	Marchant, C. J.	'The introduction and spread of *Spartina* in the UK'	Marchant (1975)
1975	Prater, A. J.	'Birds and *Spartina*'	Prater (1975)
1975	Ranwell, D. S.	'Management of *Spartina* marshes'	Ranwell (1975)
1975	Solent Protection Society	'Rothschild symposium: *Spartina* in the Solent'	Stranack and Coughlan (1975)
1975	Solent Protection Society	Discussion group established to follow-up on issues identified by the 'Rothschild symposium'	Stranack and Coughlan (1975)
1975	White, J.	'The Hythe *Spartina* reserve'	White (1975)
1976	Society for the Promotion of Nature Conservation	Renamed from Society for the Promotion of Nature Reserves	Bassett (1980)
1979	UK Government	Bern Convention adopted in 1979 and ratified in 1982	Convention on the Conservation of European Wildlife and Natural Habitats
1979	UK Government	Bonn Convention adopted in 1979 and ratified in 1985	Convention on the Conservation of Migratory Species of Wild Animals
1979–2009	European Parliament and Council	Enactment of the Birds Directive 1979 (codified in 2009)	Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds (codified version of Council Directive 79/409/EEC of 2 April 1979 on the conservation of wild birds)
1981	Coughlan, J.	'Solent shores: past and present'	Coughlan (1981)
1981	Long, S. P.	'An introduction to saltmarshes'	Long (1981)
1981	Ranwell, D. S.	'Saltmarsh: uses and restoration'	Ranwell (1981)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1981	Royal Society for Nature Conservation	Renamed from Society for the Promotion of Nature Conservation	The Wildlife Trusts (2013a)
1981	Solent Protection Society	'Solent saltmarsh symposium'	Stranack and Coughlan (1981)
1981	Tubbs, C. R.	'Current and future planning and conservation'	Tubbs (1981)
1981	UK Parliament	Enactment of the Wildlife and Countryside Act 1981 (amended in 1985)	Wildlife and Countryside Act 1981 (c. 69), Wildlife and Countryside (Amendment) Act 1985 (c. 31)
1981	Webber, N.	'Coastal and estuarine processes in the Solent'	Webber (1981)
1983	ESSO	*Spartina* planting following oil pollution contamination in Southampton Water	Brooke *et al.* (2000)
1985	UK Parliament	Enactment of the Food and Environmental Protection Act 1985	Food and Environmental Protection Act 1985 (c. 48)
1987–1998	Nature Conservancy Council and English Nature	4 Ramsar sites relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes declared in the Solent	JNCC (2008a,b,c,d)
1987–2001	Nature Conservancy Council, English Nature and Natural England	1 Special Area of Conservation (SAC) and 4 Special Protections Areas (SPA) (collectively known as 'Natura 2000') designated sites relevant to the conservation and sustainable use of intertidal mudflats and saltmarshes declared in the Solent	JNCC (2006a,b,c,d, 2011)
1989	Anon.	Sea breach of embankment in storm flooding grazing marshes, coastal defence subsequently rebuilt at Oxey marshes, Lymington	Tubbs (1999)
1990–present	SCOPAC	Sediment transport study	SCOPAC (2013)
1991	UK Parliament	Enactment of the Water Resources Act 1991	Water Resources Act 1991 (c. 57)
1992	Badman, T. and Inder, A	Solent Forum established	McHugh, K. (*pers. comm.*)
1992	European Parliament and Council	Enactment of the Habitats Directive 1992	Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora
1992	UK Government	Biodiversity Convention adopted in 1992 and ratified in 1994	Convention on Biological Diversity

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1993	Joint Nature Conservation Committee (JNCC) and Department of the Environment (DoE)	Two-day seminar to discuss key issues relating to the UK biodiversity action plan	UK Government (1994)
1993	Ministry of Agriculture, Fisheries and Food and Welsh Office	'Strategy for flood prevention in England and Wales'	MAFF and Welsh Office (1993)
1993	Motyka, J. M. and Brampton, A. H.	HR Wallingford report to Ministry of Agriculture, Fisheries and Food 'Coastal Management: Mapping of littoral cells'	Motyka and Brampton (1993)
1994	New Forest District Council and Lymington Harbour Authority	Small scale trial of saltmarsh reparation using coir fibre rolls in Lymington River	Colenutt (2001); Environment Agency (2007a)
1994	UK Government	'Biodiversity: the UK action plan'	UK Government (1994)
1994	UK Government	UK Biodiversity Steering Group established to implement the UK biodiversity action plan	UK Government (1994)
1994–2010	UK Parliament	Enactment of the Habitats Regulations 1994–2010	The Conservation (Natural Habitats, &c.) Regulations (SI 1994 No. 2716), The Conservation of Habitats and Species Regulations (SI 2010 No. 490)
1995	Bradbury, A. P.	'Western Solent saltmarsh study'	Bradbury (1995)
1996	Cundy, A. B. and Croudace, I. W.	'Sediment accretion and recent sea-level rise in the Solent'	Cundy and Croudace (1996)
1996	UK Government bodies, local authorities and NGOs	Sussex Biodiversity Partnership established	Sussex Biodiversity Partnership (2013)
1997	Chichester Harbour Conservancy	Managed realignment following sea breaching of coastal defences at Thornham Point	ABPmer (2010)
1997	East Solent Coastal Group	'East Solent and Harbours Shoreline Management Plan'	East Solent Coastal Group (1997)
1997	Isle of Wight Council	'Isle of Wight Shoreline Management Plan'	Isle of Wight Council (1997)
1997	South Downs Coastal Group	'South Downs Shoreline Management Plan'	South Downs Coastal Group (1997)
1997	Sussex Biodiversity Partnership	'From Rio to Sussex: action for biodiversity'	Sussex Biodiversity Partnership (1997)
1997	UK Government bodies, local authorities and NGOs	Hampshire Biodiversity Partnership established	Hampshire Biodiversity Parnership (1998)
1998	Chichester Harbour Conservancy	*Spartina* planting on former car park at Bosham Harbour	Brooke *et al.* (2000)
1998	Hampshire Biodiversity Partnership	'Biodiversity action plan for Hampshire'	Hampshire Biodiversity Parnership (1998)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
1998–2001	SEMS Management Group	Solent European Marine Site (SEMS) established	SEMS Management Group (2002)
1998	UK Government	Arhus Convention adopted in 1998 and ratified in 2005	Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters
1998	Western Solent and Southampton Water Coastal Group	'Western Solent and Southampton Water Shoreline Management Plan'	Western Solent and Southampton Water Coastal Group (1998)
1999	Colenutt, A. J.	'Beneficial use of dredged material for intertidal recharge'	Colenutt (1999)
1999–2003	European Commission, English Nature, Environment Agency, Department for Environment, Food and Rural Affairs, and Natural Environment Research Council	LIFE 'Living with the sea' project	English Nature (2003); Worrall (2005)
1999	HR Wallingford	Preliminary study on potential for disposing of dredged material within Chichester Harbour	Davis (2004); H. R. Wallingford (1999)
1999	UK Biodiversity Group	'Tranche 2 action plans: Vol. 5 Maritime species and habitats'	UK Biodiversity Group (1999)
1999	UK Government bodies, local authorities and NGOs	Isle of Wight Biodiversity Partnership established	Isle of Wight Biodiversity Partnership (2013)
2000–2003	ABP	Dibden dock expansion proposal	Hurley (2003)
2000	Chichester Harbour Conservancy	Regulated tidal exchange at Chalkdock marsh	ABPmer (2010)
2000	European Parliament and Council	Enactment of the Water Framework Directive 2000	Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy
2000–2002	Halcrow Group Ltd	'Futurecoast' study commissioned by Department for Environment, Food and Rural Affairs, and National Assembly for Wales in 2000, completed by Halcrow Group Ltd in 2002	Barter *et al.* (2003)
2000	Johnson, D. E.	'Ecological restoration options for the Lymington-Keyhaven saltmarshes'	Johnson (2000)
2000–2005	New Forest District Council	'In-house' studies related to the conservation and sustainable use of intertidal mudflats and saltmarshes	Colenutt, A. (*pers. comm.*)

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Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
2000	UK Parliament	Enactment of the Countryside and Rights of Way Act 2000	Countryside and Rights of Way Act 2000 (c. 37)
2001	ABPmer	Trial of beneficial use of dredged materials for intertidal mudflat and saltmarsh reparation at Hythe	Hurley (2003)
2001	Hudson, M. D.	'Patterns in time and space on Solent saltmarshes'	Hudson (2001)
2002	Baily, B., Pearson, A. W., Collier, P. and Fontana, D.	'Mapping the intertidal vegetation of the harbours of southern England for water quality management'	Baily *et al.* (2002)
2003	Bray and Cottle	'Solent coastal habitat management plan' (Solent CHaMP)	Bray and Cottle (2003)
2003	Hampshire and Isle of Wight Wildlife Trust	Lower Test realignment proposed	Chatters (2003)
2003	Hampshire Biodiversity Partnership	'Hampshire Coastal Habitat Action Plan'	Hampshire Biodiversity Parnership (2003)
2003	UK Parliament	Enactment of the Water Environment Regulations 2003	Water Environment (Water Framework Directive) (England and Wales) Regulations (SI 2003 No. 3242)
2004	Chichester Harbour Conservancy	Trial disposal of maintenance dredged materials from Chichester Marina at Treloar Hole, Chichester Harbour	Davis (2005a)
2004–present	Environment Agency	Southern regional habitat creation programme	Carina and Keskitalo (2010)
2004	Island 2000 Trust	Managed realignment at Thorness Bay, Isle of Wight	ABPmer (2010)
2004	Isle of Wight Biodiversity Partnership	'Isle of Wight Biodiversity Action Plan / Solent Coastal Habitat Action Plan'	Isle of Wight Biodiversity Partnership (2004)
2004	Royal Society of Wildlife Trusts	Renamed from Royal Society for Nature Conservation	The Wildlife Trusts (2013a)
2004	Sussex Biodiversity Partnership	'Estuaries Habitat Action Plan'	Sussex Biodiversity Partnership (2004)
2005	ABP	25 ha of un-designated land purchased at Chidham, Chichester Harbour, for future managed realignment	Davis (2005b)
2005	Bray, S.	'The long-term recovery of the bioindicator species *Nucella lapillus* from tributyltin pollution'	Bray (2005)
2005	Maritime Coastguard Agency	Wightlink's 'C-class' ferries determined unsuitable for operation	ERM (2010b)
2006	Atkins	'Isle of Wight environmental mitigation study'	Atkins (2006)

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Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
2006	Environment Agency	Farlington marshes managed realignment consultation for the Portchester Castle to Emsworth draft coastal defence strategy	Environment Agency (2009b)
2007	Baily, B. and Pearson, A. W.	'Change detection mapping and analysis of saltmarsh areas'	Baily and Pearson (2007)
2007	BRANCH Partnership	'Planning for biodiversity in a changing climate'	BRANCH Partnership (2007)
2007	Chichester Harbour Conservancy	Maintenance dredge materials from Northney Marina disposed at Treloar Hole, Chichester Harbour	Dredging News Online (2007)
2007	Cope, S. N., Bradbury, A. P. and Gorczynska, M.	'A strategic approach to managing mudflat and saltmarsh loss in the Solent'	Cope *et al.* (2007a)
2007	Cope, S. N., Bradbury, A. P., McHugh, K. and Lambert, C.	'The urgent need for compensatory habitat across the Solent'	Cope *et al.* (2007b)
2007	European Parliament and Council	Enactment of the Floods Directive 2007	Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks
2007	Hodge, M. and Johnson, D.	'Constraint mapping as a means of further refining saltmarsh re-creation opportunities for the UK Solent region'	Hodge and Johnson (2007)
2007	Quaresma, V., Bastos, A. and Amos, C. L.	'Sedimentary processes over and intertidal flat — A field investigation at Hythe marshes'	Quaresma *et al.* (2007)
2007	Wightlink	Initial application for planning consent for harbour works at Lymington to accommodate new 'W-class' ferries	ERM (2010b)
2008	Barham, P.	'The Habitats Directive and port development'	Barham (2008)
2008	Collins, T.	'Conserving dynamic coastlines: tackling climate change'	Collins (2008)
2008	Cope, S.N., Bradbury, A.P. and Gorczynska, M.	'Solent dynamic coast project: a tool for SMP 2'	Cope *et al.* (2008)
2008	European Parliament and Council	Enactment of the Marine Strategy Framework Directive 2008	Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy
2008	Gardiner, S., Nicholls, R. J., Spencer, T., Hanson, S., Richards, J. and Zhang, Z.	'Coastal habitats, climate change and spatial planning: Lessons from the Solent region'	Gardiner *et al.* (2008)

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Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
2008	Hudson, M. D., Bray, S., Williams, E. and Lloyd-Jones, D.	'Beneficial use of dredge spoil: a Solent feasibility study'	Hudson *et al.* (2008)
2008	Huggett, D.	'Saltmarsh restoration and habitat creation: Environment Agency's perspective'	Huggett (2008a)
2008	Huggett, D.	'The importance of saltmarshes for flood risk management'	Huggett (2008b)
2008	Jolley, R. and Reynolds, R.	'Southern Regional Habitat Creation Programme: delivering environmental outcomes in the Solent'	Jolley and Reynolds (2008)
2008	McMullon, C.	'The importance of saltmarshes for biodiversity'	McMullon (2008)
2008	Pitt, M.	Learning lessons from the 2007 floods report	Pitt (2008)
2008	Scott, C.	'Wallasea Island wetland creation projects'	Scott (2008)
2008	Solent Protection Society	'What future for the Solent's saltmarshes?' conference	Inder and Ansell (2008)
2008	Steyl, I., Kuhn, P., Bray, S., Lloyd-Jones, D., Larter, M. and Lord, B.	'Assessing the use of terrestrial LIDAR to monitor sediment change in a Solent system'	Steyl *et al.* (2008)
2008	Townend, I.	'A summary of ongoing research related to saltmarsh and managed realignment'	Townend (2008)
2008	Williams, E.	'Change in sediment stores around an active port: a case study of Southampton Water'	Williams (2008)
2008/09	Chichester Harbour Conservancy	Maintenance dredge materials from Emsworth Yacht Harbour disposed at Treloar Hole, Chichester Harbour	Dredging News Online (2008)
2009	Chen, Y.	'The development of a tidal creek system in a low energy environment: Beaulieu estuary'	Chen (2009)
2009	Environment Agency	'Pagham to East Head coastal defence strategy'	Environment Agency, Chichester District Council and Arun District Council (2009)
2009	Environment Agency	'Portchester Castle to Emsworth draft coastal defence strategy'	Environment Agency (2009b)
2009	Environment Agency	'South east river basin district management plan' including Appropriate Assessment	Environment Agency (2009c)
2009	UK Parliament	Enactment of the Flood Risk Regulations 2009	Flood Risk Regulations (SI 2009 No. 3042)
2009	UK Parliament	Enactment of the Marine and Coastal Access Act 2009	Marine and Coastal Access Act 2009 (c. 23)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
2010	Chichester Harbour Conservancy	Maintenance dredge materials from Sparkes Marina disposed at Treloar Hole, Chichester Harbour	Dredging News Online (2010)
2010	Isle of Wight Council	'Isle of Wight Shoreline Management Plan 2' including Appropriate Assessment	Isle of Wight Council (2010)
2010	Lymington Harbour Commissioners	Construction of new breakwater (phase 1) completed	Black and Veatch (2012)
2010	New Forest District Council	'North Solent Shoreline Management Plan 2' including Appropriate Assessment	New Forest District Council (2010)
2010	Rupp, S.	'The status and future of managed realignment of coastal flood plains in western Europe: a comparative study'	Rupp (2010)
2010	Sussex Biodiversity Partnership	'Intertidal mudflat Habitat Action Plan' and 'Saltmarsh Habitat Action Plan'	Sussex Biodiversity Partnership (2010a,b)
2010	Tsuzaki, T.	'*Spartina anglica* population and environmental studies within the Solent saltmarsh system'	Tsuzaki (2010)
2010	UK Parliament	Enactment of the Flood and Water Management Act 2010	Flood and Water Management Act 2010 (c. 29)
2010	UK Parliament	Enactment of the Marine Strategy Regulations 2010	Marine Strategy Regulations (SI 2010 No. 1627)
2010	Wightlink	Revised application for planning consent including Appropriate Assessment	ERM (2010b)
2010	Williams, E., Bray, S., Lloyd-Jones, D., Steyl, I., Hudson, M. D. and Nicholls, R. J.	'Scoping study — Site analysis for potential beneficial dredge spoil use for restoration and recharge of intertidal soft sediment resources within the Solent'	Williams *et al.* (2010)
2012	Esteves, L. S., Foord, J. and Draux, H.	'The shift from hold-the-line to management retreat and implications to coastal change: Farlington Marshes, a case of conflicts'	Esteves *et al.* (2012)
2012	Foster, N.	'Sustainable mudflats and saltmarshes: From systemic understanding to systemically feasible and desirable actions' workshop	
2012	Lymington Harbour Commissioners	Marina marsh recharge works to mitigate for the adverse impacts of breakwater construction	Black and Veatch (2012)
2012	Wightlink	Boiler Marsh recharge and habitat creation works to mitigate for the adverse impacts of new 'W-class' ferry operations	ABPmer (2012)

Continued...

Table C.1 List of events pertaining to the conservation and sustainable use of intertidal mudflat and saltmarsh in the Solent from 1800 to 2016 continued

Year	Name	Event	References
2013	Environment Agency	Medmerry managed realignment scheme to mitigate coastal flood risk and to compensate for 'coastal squeeze' of intertidal mudflats and saltmarshes from 'hold-the-line' policies in the North Solent Shoreline Management Plan	Environment Agency (2009a, 2012)
In progress	Lloyd-Jones, D.	'Multi-criteria decision analysis for assessing beneficial use sites'	Lloyd-Jones (in progress)
In progress	Williams, E.	'The impact of changing sediment budgets on the intertidal zone around an active port: a case study of Southampton Water, UK'	Williams (in progress)
2015	Environment Agency	Flood risk management plans to be produced and published by 2015	Colenutt, A. (*pers. comm.*)
2016	Environment Agency	Programme of measures for achieving Good Environmental Status	Colenutt, A. (*pers. comm.*)

Appendix D

Participant information sheet and consent form

Participants were required to read the Participant Information Sheet and sign the Consent Form prior to participating in this research.

UNIVERSITY OF Southampton

Participant information sheet (Version 1.0)

Research project title:	Sustainable mudflats and saltmarshes: from systemic understanding to systemically feasible and desirable actions
Researcher:	Natalie M. Foster
Ethics approval reference:	8474

Please read this information carefully before deciding whether to participate in this research project. If you decide to participate, you will be asked to sign a consent form.

What is the research about?

The adoption of the Convention on Biological Diversity at the Earth Summit in Rio de Janeiro, Brazil in 1992 committed the UK to conserve and sustainably use biological diversity for the benefit of present and future generations. Twenty years on, and despite no net loss policies and reparation schemes, intertidal mudflat and saltmarsh losses continue to exceed gains in the UK.

This research aims to develop a decision support system (DSS) to identify and implement systemically feasible and desirable actions through a multi-stakeholder learning process in order to further progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes.

Using the Solent region as a case study, the research will:

1. Explore and analyse the past causes of current understanding and practices;
2. Use the insights gained from the post-hoc analysis to develop a DSS;
3. Validate the DSS via action research;
4. Critically analyse whether the DSS was appropriate in this context;
5. Consider the use of the DSS in similar future contexts.

Why have I been asked to participate?

Research participants will be local stakeholders, e.g. Government bodies, advisors, consultants, port authorities, NGOs, general public. Participants have been asked to take part because they have been identified as a local stakeholder, that is, they have a stake or interest in the research situation.

What will happen if I participate?

The research methodology comprises the following stages:

1. Via interviews, participants will be asked to confirm their role and perspective of the current situation, and hence, to confirm that links made on a diagram of events are correct. Where links are thought to be incorrect, or absent, participants will be asked to suggest amendments.
2. Participants will be asked to attend and discuss a presentation of results based on work supported by the interviews.
3. Via workshops, participants will be asked to work with other stakeholders through a decision making process (designed by this research project) to identify and implement systemically feasible and desirable actions to further progress towards the conservatation and sustainable use of intertidal mudflats and saltmarshes.

4. Participants will be asked to attend and discuss a presentation of results from the workshops. This will include giving feedback (verbal/written) on the use of the DSS.

Participants in the research project may be involved in all or some of the stages. Participation is voluntary at all stages throughout the research project. Consent to participate is **not** a commitment to take part in all of the stages, but rather, a consent of agreement to participate in the research project and to the data obtained as a result of participation to be used for the purpose of the research project.

Are there any benefits in taking part?
Participation in the research project presents an opportunity to disseminate your present understanding of the research situation, to meet new colleagues and to develop with them expertise in environmental decision making. Furthermore, it is hoped that the research will lead to the identification and implementation of actions to further progress towards the conservation and sustainable use of intertidal mudflats and saltmarshes in the Solent region.

Are there any risks involved?
There is minimal risk involved in taking part in the research. A risk assessment for the research project has identified all risks as 'acceptable'. A summary of this risk assessment is available on request.

Will participation be confidential?
Participant anonymity and confidentiality cannot be maintained due to the social, multi-stakeholder learning aspect of the research.

What happens if I change my mind?
Participants may withdraw consent at any time without their legal rights being affected.

What happens if something goes wrong?
In the unlikely case of concern or complaint, please contact Dr. Martina Prude, Head of Research Governance:

Email: rgoinfo@soton.ac.uk
Tel: +44 (0) 2380 59 50 58

Where can I get more information?
For further information about this research project, please contact Natalie Foster:

Email: natalie.foster@soton.ac.uk
Tel: +44 (0)7800 87 57 80

Consent form (Version 1.0)

Research project title: Sustainable mudflats and saltmarshes: from systemic understanding to systemically feasible and desirable actions

Researcher: Natalie M. Foster

Ethics approval reference: 8474

Please initial the box(es) if you agree with the statement(s):

☐ I have read and understood the participant information sheet (Version 1.0) and I have had the opportunity to ask questions about the research project.

☐ I consent to participate in the research project and I consent to the data obtained as a result of my participation to be used for the purpose of the research project.

☐ I understand my participation is voluntary and I may withdraw consent at any time without my legal rights being affected.

Participant name (print name):

Participant signature:

Researcher name (print name):

Researcher signature:

Date:

Appendix E

Workshop evaluation questionnaire

Workshop participants were asked to complete the evaluation questionnaire following the four working sessions.

UNIVERSITY OF Southampton

Workshop evaluation sheet

Research project title:	Sustainable mudflats and saltmarshes: from systemic understanding to systemically feasible and desirable actions
Researcher:	Natalie M. Foster
Ethics approval reference:	8474

As the comments, criticisms and suggestions of participants are very important in determining the usefulness and future direction of this research project, please complete this confidential workshop evaluation sheet.

Name (optional):

Organization (optional):

To what extent did the workshop achieve its objective, i.e. to enable decisions to be made?

Did the workshop make the best use of resources such as time?

To what extent did the workshop achieve its espoused purpose, i.e. to render actions possible to conserve and sustainably use intertidal mudflats and saltmarshes?

How can the decision-making process be further improved?

Was the decision making process appropriate in this context?

In what types of future complex decision making situations do you perceive that the decision making process could be applied, e.g. nuclear power?

Any further comments?

Thank you,
Natalie

Appendix F

System dynamics simulation model

The system dynamics simulation model used in the pilot study workshop was based upon a generic strip of land (Figure F.1). The structure of the model is shown in Figure F.2, along with the associated equations. Table F.1 lists the simulation model data inputs for each option evaluated in the pilot study workshop.

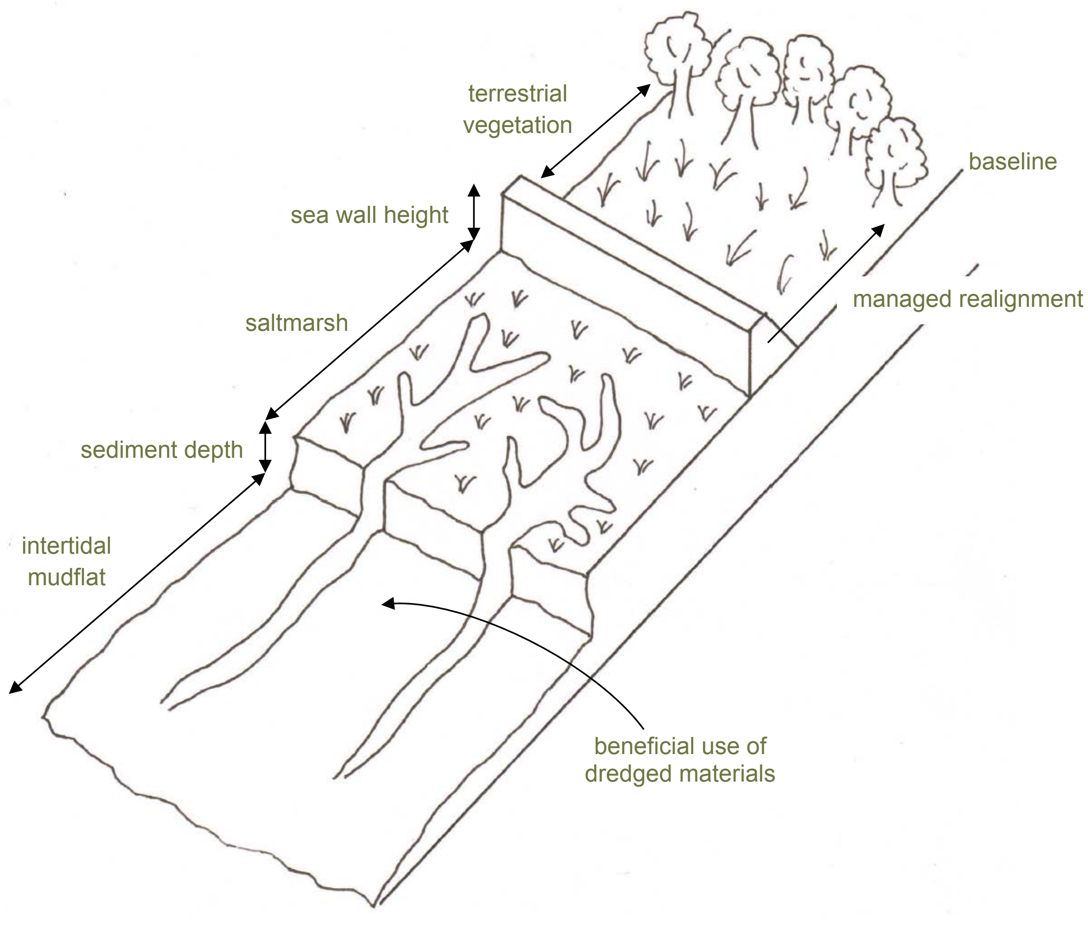


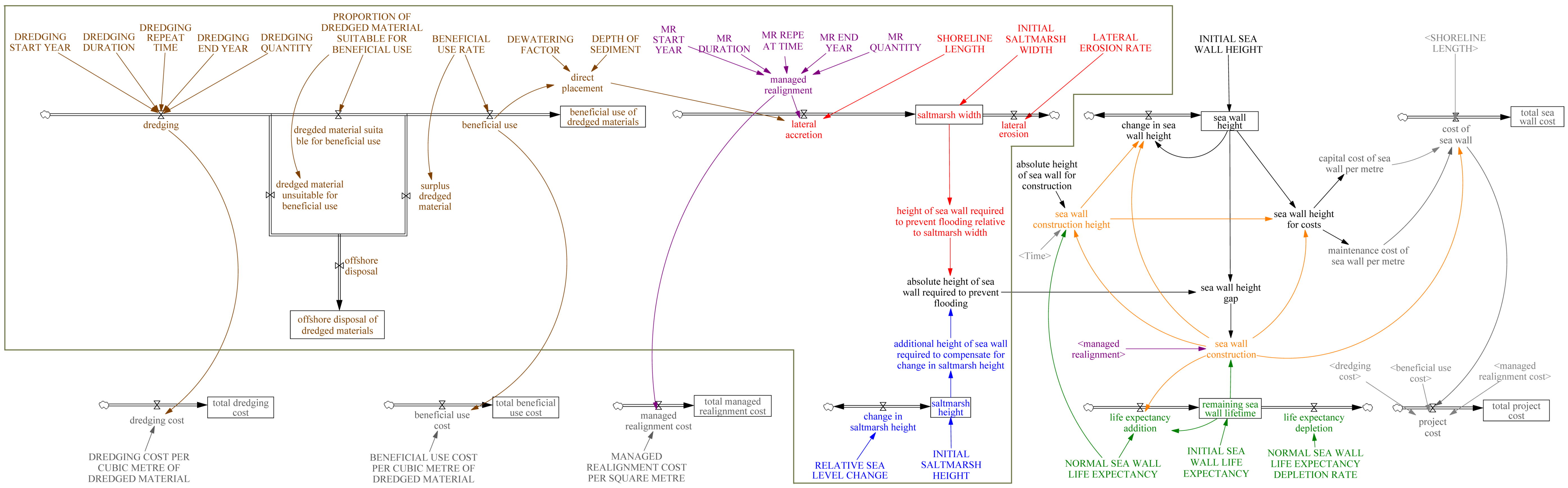
Figure F.1 Generic strip of land which formed the basis for the system dynamics simulation model used in the pilot study workshop

The model was constructed using VENSIM^{TM} software by VENTANA Systems. The software and user manuals can be accessed from the VENTANA Systems website (www.vensim.com). The model could also be constructed using alternative software such as STELLA^{TM} by ISEE Systems (http://www.iseesystems.com/softwares/Education/StellaSoftware.aspx).

Table F.1 System dynamics simulation model data inputs for each option evaluated in the pilot study workshop (text colours are consistent with Figure F.2)

	Do nothing	Dredging and sea wall construction	Dredging, sea wall construction and beneficial use of dredged materials	Dredging, sea wall construction and managed realignment
Dredging start year	2012	2012	2012	2012
Dredging duration	0.5	0.5	0.5	0.5
Dredging repeat time	5	5	5	5
Dredging end year	2112	2112	2112	2112
Dredging quantity	0	50000	50000	50000
Proportion of dredged material suitable for beneficial use	0.8	0.8	0.8	0.8
Beneficial use rate	0	0	1	0
Dewatering factor	4	4	4	4
Depth of sediment	1	1	1	1
Managed realignment start year	2012	2012	2012	2012
Managed realignment duration	0.5	0.5	0.5	0.5
Managed realignment repeat time	100	100	100	100
Managed realignment end year	2112	2112	2112	2112
Managed realignment quantity	0	0	0	200000
Shoreline length	1000	1000	1000	1000
Initial saltmarsh width	50	50	50	50
Lateral erosion rate	2	2	2	2
Relative sea level change	0.002	0.002	0.002	0.002
Initial saltmarsh height	0	0	0	0
Initial sea wall height	6	6	6	6
Normal sea wall life expectancy	25	25	25	25
Initial sea wall life expectancy	10	10	10	10
Normal sea wall life expectancy depletion rate	1	1	1	1
Dredging cost per cubic metre of dredged material[a]	10	10	10	10
Beneficial use cost per cubic metre of dredged material[b]	1.54	1.54	1.54	1.54
Managed realignment cost per square metre[c]	2.60	2.60	2.60	2.60

[a] The dredging cost per cubic metre is the average value derived from costs stated in relevant data
[b] The beneficial use cost per cubic metre of dredge material is the average value derived from 10 schemes
[c] The managed realignment cost per square metre is the average value derived from 20 schemes (excluding one anomalous value)



absolute height of sea wall for construction (in metres) := GET VDF DATA('set data inputs' , 'absolute height of sea wall required to prevent flooding' , 0 , 1)
absolute height of sea wall required to prevent flooding (in metres) = height of sea wall required to prevent flooding relative to saltmarsh width + additional height of sea wall required to compensate for change in saltmarsh height
additional height of sea wall required to compensate for change in saltmarsh height (in metres) = saltmarsh height
beneficial use (in cubic metres) = BENEFICIAL USE RATE * dredged material suitable for beneficial use
beneficial use cost (in £) = beneficial use * beneficial use cost per cubic metre of dredged material
beneficial use cost per cubic metre of dredged material (in £) == 1.54
beneficial use of dredged materials (in cubic metres) = INTEG (beneficial use , 0)
BENEFICIAL USE RATE := GET VDF DATA('set data inputs' , 'BENEFICIAL USE RATE' , 0 , 1)
capital cost of sea wall per metre (in £) = WITH LOOKUP (sea wall height for costs , ([(3,0)(15,8000)],(3,400),(4,500),(5,800),(6,1500),(12,5000),(15,7000)))
change in saltmarsh height (in metres per year) =RELATIVE SEA LEVEL CHANGE
change in sea wall height (in metres) =IF THEN ELSE(sea wall construction = 1 , (sea wall construction height - sea wall height) , 0)
cost of sea wall (in £) = IF THEN ELSE(sea wall construction = 1 , capital cost of sea wall per metre * SHORELINE LENGTH , maintenance cost of sea wall per metre * SHORELINE LENGTH)
DEPTH OF SEDIMENT (in metres) := GET VDF DATA('set data inputs' , 'DEPTH OF SEDIMENT' , 0 , 1)
DEWATERING FACTOR := GET VDF DATA('set data inputs' , 'DEWATERING FACTOR' , 0 , 1)
direct placement (in square metres) = beneficial use / (DEPTH OF SEDIMENT * DEWATERING FACTOR)
dredged material unsuitable for beneficial use (in cubic metres) = (1 - PROPORTION OF DREDGED MATERIAL SUITABLE FOR BENEFICIAL USE) * dredging
dredging (in cubic metres per year) = DREDGING QUANTITY * (PULSE TRAIN(DREDGING START YEAR, DREDGING DURATION, DREDGING REPEAT TIME , DREDGING END YEAR))
dredging cost (in £) = dredging cost per cubic metre of dredged material * dredging
dredging cost per cubic metre of dredged material (in £) == 10
DREDGING DURATION (in years): INTERPOLATE::= GET VDF DATA('set data inputs' , 'DREDGING DURATION' , 0 , 1)
DREDGING END YEAR: INTERPOLATE::= GET VDF DATA('set data inputs' , 'DREDGING END YEAR' , 0 , 1)
DREDGING QUANTITY (in cubic metres): INTERPOLATE::= GET VDF DATA('set data inputs' , 'DREDGING QUANTITY' , 0,1)
DREDGING REPEAT TIME (in years): INTERPOLATE::= GET VDF DATA('set data inputs' , 'DREDGING REPEAT TIME' , 0 , 1)
DREDGING START YEAR (in years): INTERPOLATE::= GET VDF DATA('set data inputs', 'DREDGING START YEAR' , 0,1)
dredged material suitable for beneficial use (in cubic metres) =PROPORTION OF DREDGED MATERIAL SUITABLE FOR BENEFICIAL USE * dredging
height of sea wall required to prevent flooding relative to saltmarsh width (in metres) = WITH LOOKUP (saltmarsh width , ([(0,0)-(80,12)],(0,12),(6,6),(30,5),(60,4),(80,3)))
INITIAL SALTMARSH HEIGHT (in metres) := GET VDF DATA('set data inputs' , 'INITIAL SALTMARSH HEIGHT' , 0 , 1)
INITIAL SALTMARSH WIDTH (in metres) := GET VDF DATA('set data inputs' , 'INITIAL SALTMARSH WIDTH' , 0 , 1)
INITIAL SEA WALL HEIGHT (in metres) := GET VDF DATA('set data inputs' , 'INITIAL SEA WALL HEIGHT' , 0 , 1)
INITIAL SEA WALL LIFE EXPECTANCY (in years) := GET VDF DATA('set data inputs' , 'INITIAL SEA WALL LIFE EXPECTANCY' , 0 , 1)
lateral accretion (in metres) = (direct placement / SHORELINE LENGTH) + (managed realignment / SHORELINE LENGTH)
lateral erosion (in metres per year) = LATERAL EROSION RATE
LATERAL EROSION RATE (in metres per year) := GET VDF DATA('set data inputs' , 'LATERAL EROSION RATE' , 0 , 1)
life expectancy addition (in years) =IF THEN ELSE(sea wall construction = 1, -remaining sea wall lifetime + NORMAL SEA WALL LIFE EXPECTANCY , 0)
life expectancy depletion (in years) =NORMAL SEA WALL LIFE EXPECTANCY DEPLETION RATE
maintenance cost of sea wall per metre (in £) = WITH LOOKUP (sea wall height for costs , ([(3,0)-(15,70)],(3,1),(4,5),(5,30),(12,50),(15,70)))
managed realignment (in square metres) =MR QUANTITY * PULSE TRAIN(MR START YEAR, MR DURATION , MR REPEAT TIME , MR END YEAR)
managed realignment cost (in £) =managed realignment * MANAGED REALIGNMENT COST PER SQUARE METRE
MANAGED REALIGNMENT COST PER SQUARE METRE (in £) == 2.6
MR DURATION (in years) := GET VDF DATA('set data inputs', 'MR DURATION' , 0 , 1)
MR END YEAR (in years) := GET VDF DATA('set data inputs', 'MR END YEAR' , 0 , 1)
MR QUANTITY := GET VDF DATA('set data inputs', 'MR QUANTITY' , 0 , 1)
MR REPEAT TIME (in years) := GET VDF DATA('set data inputs', 'MR REPEAT TIME' , 0 , 1)
MR START YEAR (in years) := GET VDF DATA('set data inputs', 'MR START YEAR' , 0 , 1)
NORMAL SEA WALL LIFE EXPECTANCY (in years) := GET VDF DATA('set data inputs' , 'NORMAL SEA WALL LIFE EXPECTANCY' , 0 , 1)
NORMAL SEA WALL LIFE EXPECTANCY DEPLETION RATE (in years per year) := GET VDF DATA('set data inputs' , 'NORMAL SEA WALL LIFE EXPECTANCY DEPLETION RATE' , 0 , 1)
offshore disposal (in cubic metres) = dredged material unsuitable for beneficial use + surplus dredged material
offshore disposal of dredged materials (in cubic metres) = INTEG (offshore disposal , 0)
project cost (in £) = dredging cost + beneficial use cost + cost of sea wall + managed realignment cost
PROPORTION OF DREDGED MATERIAL SUITABLE FOR BENEFICIAL USE := GET VDF DATA('set data inputs' , 'PROPORTION OF DREDGED MATERIAL SUITABLE FOR BENEFICIAL USE' , 0 , 1)
RELATIVE SEA LEVEL CHANGE (in metres per year) := GET VDF DATA('set data inputs' , 'RELATIVE SEA LEVEL CHANGE' , 0 , 1)
remaining sea wall lifetime (in years) = INTEG (life expectancy addition - life expectancy depletion , INITIAL SEA WALL LIFE EXPECTANCY)
saltmarsh height (in metres) = INTEG (change in saltmarsh height , INITIAL SALTMARSH HEIGHT)
saltmarsh width (in metres) = INTEG (lateral accretion - lateral erosion , INITIAL SALTMARSH WIDTH)
sea wall construction =IF THEN ELSE((sea wall height gap<0):OR:(remaining sea wall lifetime<=0):OR:(managed realignment>1), 1, 0)
sea wall construction height (in metres) = SAMPLE IF TRUE(sea wall construction = 1 , GET DATA MAX(absolute height of sea wall for construction , Time , Time + NORMAL SEA WALL LIFE EXPECTANCY) , absolute height of sea wall for construction)
sea wall height (in metres) = INTEG (change in sea wall height , INITIAL SEA WALL HEIGHT)
sea wall height for costs (in metres) = SAMPLE IF TRUE(sea wall construction = 1 , sea wall construction height , sea wall height)
sea wall height gap (in metres) = sea wall height - absolute height of sea wall required to prevent flooding
SHORELINE LENGTH (in metres) := GET VDF DATA('set data inputs' , 'SHORELINE LENGTH' , 0 , 1)
surplus dredged material (in cubic metres) = (1 - BENEFICIAL USE RATE) * dredged material suitable for beneficial use
total beneficial use cost (in £) = INTEG (beneficial use cost , 0)
total dredging cost (in £) = INTEG (dredging cost , 0)
total managed realignment cost (in £) = INTEG (managed realignment cost , 0)
total project cost (in £) = INTEG (project cost , 0)
total sea wall cost (in £) = INTEG (cost of sea wall , 0)

Figure F.2 VENSIM™ diagram of the system dynamics simulation model used in the pilot study workshop. The VENSIM™ software does not enable future values to be used during simulation; thus, to determine the absolute height of the sea wall that would need to be constructed to prevent flooding over its life expectancy (e.g. the next 25 years), the parts of the model within the dark green boundary were simulated initially and used to inform the subsequent simulation.

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Glossary

Definitions of some generalized systems concepts used in this research, adapted from: Ison (2010); Open University (2006b, 2014); Oxford University Press (2014); Pearson and Ison (1997); Reed *et al.* (2010); Wilson (1984).

Boundary	The conceptual border of a system, determined by the observer(s), which demarcates the system from its environment
Difficulty	A well-defined problem situation in which it is clear who is involved and what would constitute a solution within a given time frame (*cf.* mess)
Emergent properties	Properties emerging from a system which are not possessed by the constituent sub-systems
Environment	The context for a system of interest; that which surrounds and affects the system, and is affected by it
Intervention	The action of intervening or interfering in any situation, so as to alter its course
Measure of performance	The criteria against which the system is judged to have achieved its purpose. Data collected according to measures of performance is used to monitor and control the system
Mess	An ill-defined problem situation in which it is not clear who is involved nor what would constitute a solution within a given time frame (*cf.* difficulty)
Method	A way of doing something that is 'used as given'
Methodology	A way of doing something that can be adapted by the user(s); the conscious braiding of theory and practice in a given context
Monitoring and control	The collection and analysis of data according to measures of performance, leading to corrective actions if necessary
Situation of interest	A situation in which an individual or group of people has an interest (or stake)
Skill	The ability to do something
Social learning	Learning that takes place at a wider scale than individual or group learning — at societal scale — through social interaction between peers

System	An integrated whole in which emergent properties arise from the relationship between its parts; from the Greek *synhistanai* meaning 'to place together'
System of interest	A system in which an individual or group of people has an interest (or stake); the product of distinguishing a system in a given situation of interest
Systemic thinking	The understanding of a phenomenon within the context of a larger whole; to understand things systemically literally means to put them into a context, to establish the nature of their relationships (*cf.* systematic thinking)
Systematic thinking	Thinking which is connected with parts of a whole but in a linear, step-by-step manner (*cf.* systemic thinking)
Technique	A particular way of carrying out a task, effecting a purpose or facilitating an activity using a combination of skills and tools
Tool	Something used to assist in carrying out a task, effecting a purpose or facilitating an activity
Trap	Away of thinking which is inappropriate for the situation or issue being explored
Worldview (or *Weltanschauung*)	The view of the world which enables the observer to attribute meaning to what is observed

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